

MULTI-LEVEL SYSTEM ASSESSMENT OF THE GHANAIAN EMERGENCY, TRAUMA, AND SURGICAL CARE SYSTEM: A ROADMAP FOR DEVELOPMENT

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DEDICATION

This work is dedicated to the 71 people who died after a bus crash on the Tamale-Kintampo Road in Brong Ahafo, Ghana on February 17, 2016. The victims of this crash not only inspired this work, but also policy makers, emergency care providers, and the road safety community in Ghana to make roads and road users safer, improve post-crash care, and create a broad framework for sustained emergency care system development.

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I wish to acknowledge my incredible wife, Melissa, who supported and encouraged me to take on this project and fundamentally change the way that we assess and improve emergency, trauma, and surgical care in low-resource settings. During the four years that it took to complete these projects, we were engaged, married, lived in three countries, spent most days separated by thousands of miles, endured surgical residency, and only fell more in love. I will forever be indebted for her steadfast support and encouragement.

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Godfred Boakye was my ambassador to Ghanaian culture, confidant, colleague, and dear friend. Perhaps my greatest achievement from this work was sparking his interest in injury control, and ultimately the pursuit and completion of a master's degree in public health from Kwame University of Science and Technology in Kumasi, Ghana.

The faculty and staff at Komfo Anokye Hospital, Kwame University of Science and Technology, Ghana Health Service, Ghanaian

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DECLARATION

By submitting this dissertation, I declare that the entirety of the work contained herein is my own, original work, that I am the lead author thereof save to the extent explicitly otherwise stated, that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights, and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Further, this dissertation includes 17 original papers published in peer-reviewed journals (7 first authored publications, 10 ancillary publications) and 1 unpublished report for the Ghana Ministry of Health and the World Health Organization (WHO). The development and writing of the papers (published and unpublished) were the principal responsibility of myself and for each of the cases where this is not the case a declaration is included in the dissertation indicating the nature and extent of the contributions of co-authors.

Declarations for each first-author publication included in the dissertation can be found in Appendix 1.

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ABSTRACT

This dissertation is a compilation and evolution of a multi-level assessment of emergency, trauma and surgical care in Ghana that was designed to provide benchmarking data, identify key gaps, and outline a plan for development.

The work began with an assessment of surgical and trauma care capacity at district, regional and tertiary hospitals nationwide. The results demonstrated critical deficiencies in essential resources that limit the quality of care that could be provided to the sick and injured. However, when compared to a similar assessment a decade prior, there were notable improvements, which highlighted the potential for positive change, and identified existing opportunities for capacity building.

While this work was being completed, three major movements in global surgery and international health policy were afoot that mandated a better understanding of access to essential surgical and trauma care and evaluation and monitoring of essential surgical and trauma care. Therefore, to stay relevant and contribute meaningfully to the meta-discussion in global surgery, we set out to pilot the collection and use of these metrics in Ghana. In addition to the assessments of capacity, piloting of the new metrics was done by: i) enumerating all operations done in the country in one year, ii) describing geospatial access to surgical care, and iii) modeling the risk of catastrophic expenditure for people who need surgery.

During this phase of the work, several findings were noted. First, it seemed that surgical capacity was not directly associated to surgical output, which contrasted with the current assumptions regarding surgical capacity assessments and capacity building initiatives. Therefore, we set out to examine this relationship with data from the national capacity assessment and surgical

enumeration. This study confirmed our suspicions: there was no association between capacity and output. The findings suggested that several non-measured factors were important for improving output, such as differential barriers to care, process components (e.g., protocols, policies, emotional infrastructure), and system coordination. Therefore, we sought to further characterize these components and develop a system-wide roadmap for emergency, trauma, and surgical care system development. This was done by: developing, piloting and expanding a barriers to care assessment tool; developing context-appropriate audit filters to investigate the trend of process metrics; and developing and piloting the World Health Organization (WHO) Emergency Care System Assessment Tool (ECSAT) in Ghana.

The data from the entire work allowed for a rich description of the state of emergency, trauma, and surgical care in the country, identification of the key gaps, and creation of a roadmap for development. The latter was done in conjunction with the Ghana Ministry of Health and was turned over to them for implementation and monitoring by in-country partners. The work in total demonstrated the utility of multi-level assessments in planning for strategic development of the healthcare system, and contributed meaningfully to the global surgery movement with regards to tool creation and piloting of several novel metrics.

OPSOMMING

Hierdie proefskrif is 'n samestelling en ontwikkelingsgang van 'n multivlak-assessering van nood-, trauma- en chirurgiese sorg in Ghana wat ontwerp is om normdata te verskaf, die belangrikste leemtes te identifiseer, en 'n plan vir ontwikkeling uiteen te sit.

Die werk het met 'n assessering van chirurgiese en traumasorgkapasiteit by distriks-, streeks- en tersiêre hospitale landswyd begin. Die resultate het kritiese tekortkominge in noodsaaklike hulpbronne uitgewys, wat die gehalte van die voorsiene sorg aan siekes en beseerdes beperk. In vergelyking met 'n soortgelyke assessering 'n dekade vantevore, was daar egter merkbare verbeterings, wat die potensiaal vir positiewe verandering beklemtoon het en bestaande geleenthede vir kapasiteitsbou aangedui het.

Terwyl hierdie werk uitgevoer is, was daar drie groot bewegings in wêreldwye chirurgie en internasionale gesondheidsbeleid aan die gang wat 'n beter begrip van toegang tot noodsaaklike chirurgiese en traumasorg, en die evaluering en monitering van noodsaaklike chirurgiese en traumasorg vereis. Om dus relevant te bly en betekenisvol tot die metabespreking in wêreldwye chirurgie by te dra, het ons met die insameling en gebruik van hierdie parameters in Ghana begin. Benewens die kapasiteitsassessering, is die loodsing van die nuwe parameters gedoen deur: i) die optelling van alle operasies wat in een jaar in die land uitgevoer is; ii) die beskrywing van die georuimtelike toegang tot chirurgiese sorg; en iii) die modellering van die risiko van katastrofiese uitgawes vir mense wat chirurgiese ingrepe benodig.

Gedurende hierdie fase van die werk is verskeie bevindings aangeteken. Eerstens blyk dit dat chirurgiese kapasiteit nie direk met chirurgiese uitset verband hou nie, wat strydig is met die

huidige aannames ten opsigte van chirurgiese kapasiteitassesserings en kapasiteitsbou-inisiatiewe. Daarom het ons hierdie verband met data uit die nasionale kapasiteitassessering en die chirurgiese optelling ondersoek. Hierdie studie het ons vermoedens bevestig: daar was geen verband tussen kapasiteit en uitset nie. Die bevindings suggereer dat verskeie nie-gemete faktore belangrik was om uitset te verbeter, soos differensiële hindernisse ten opsigte van sorg, proseskomponente (byvoorbeeld protokolle, beleide, emosionele infrastruktuur), en stelselkoördinasie. Daarom het ons probeer om hierdie komponente verder te karakteriseer en 'n stelselwye padkaart vir nood-, trauma- en chirurgiese sorgstelselontwikkeling te ontwikkel. Dit is gedoen deur: die ontwikkeling, loodsing en uitbreiding van 'n assesseringsinstrument om hindernisse tot sorg te bepaal; die ontwikkeling van konteks-gepaste ouditfilters om die tendens van prosesparameters te ondersoek; en die ontwikkeling en loodsing van die Wêreldgesondheidsorganisasie se Noodsorgstelselassessering-instrument in Ghana.

Die data uit die werk in geheel maak voorsiening vir 'n omvangryke beskrywing van die noodtoestand-, trauma-, en chirurgiese sorg in die land; die identifisering van die belangrikste leemtes; en die skep van 'n padkaart vir ontwikkeling. Laasgenoemde is in samewerking met Ghana se Ministerie van Gesondheid gedoen en is aan hulle oorgedra vir implementering en monitering deur vennote in die land. Die werk in geheel het die nut van multivlak-assesserings in die beplanning vir die strategiese ontwikkeling van die gesondheidsorgstelsel uitgewys, en 'n betekenisvolle bydrae tot die wêreldwye chirurgiese beweging gemaak sover dit die skepping van instrumente en die loodsing van verskeie nuwe parameters betref.

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ABBREVIATIONS

CHAG – Christian Health Association of Ghana
ECS – Emergency care system
EESCA – Emergency and essential surgical care and anesthesia
ESTC – Emergency, surgical and trauma care
GDP – Gross domestic product
GHS – Ghana Health Service
KNUST – Kwame Nkrumah University of Science and Technology
LMIC – Low- and middle-income countries
STC – Surgical and trauma care
WHO ECSA – World Health Organization’s Emergency Care System Assessment Tool
WHO – World Health Organization
1mCHW – 1 Million Community Health Workers

LISTING OF PUBLICATIONS

FIRST AUTHOR PUBLICATIONS

Declarations for first author publications included in the dissertation are available in Appendix 1.

1. Stewart B. T., Quansah R., Gyedu A., et al. Strategic Assessment of Trauma Care Capacity in Ghana. *World J Surg.* 2015;39(10):2428-40.
2. Stewart B. T., Quansah R., Gyedu A., et al. Serial Assessment of Trauma Care Capacity in Ghana in 2004 and 2014. *JAMA Surg.* 2015:1-8.
3. Stewart B. T., Gyedu A., Gaskill C., et al. Exploring the Relationship Between Surgical Capacity and Output in Ghana: Current Capacity Assessments May Not Tell the Whole Story. *World J Surg.* 2018 Oct;42(10):3065-3074.
4. Stewart B. T., Gyedu A., Quansah R., et al. District-level hospital trauma care audit filters: Delphi technique for defining context-appropriate indicators for quality improvement initiative evaluation in developing countries. *Injury.* 2016;47(1):211-9.
5. Stewart B. T., Gyedu A., Abantanga F., et al. Barriers to Essential Surgical Care in Low- and Middle-Income Countries: A Pilot Study of a Comprehensive Assessment Tool in Ghana. *World J Surg.* 2015 Nov;39(11):2613-21.
6. Stewart B. T., Tansley G., Gyedu A., et al. Mapping Population-Level Spatial Access to Essential Surgical Care in Ghana Using Availability of Bellwether Procedures. *JAMA Surg.* 2016;151(8):e161239.
7. Stewart B. T. Consensus-Based Action Priorities From an Assessment of the Ghana Emergency Care System: A Roadmap for Development. Geneva, Switzerland: World Health Organization, 2016 May 5, 2016. Report No.: 1.

RELATED ANCILLARY PUBLICATIONS

1. Ankomah J., Stewart B. T., Oppong-Nketia V., et al. Strategic assessment of the availability of pediatric trauma care equipment, technology and supplies in Ghana. *J Pediatr Surg.* 2015.
2. Gyedu A., Abantanga F., Boakye G., et al. Barriers to essential surgical care experienced by women in the two northernmost regions of Ghana: a cross-sectional survey. *BMC Womens Health.* 2016;16:27.
3. Gyedu A., Agbedinu K., Dalwai M., et al. Triage capabilities of medical trainees in Ghana using the South African triage scale: an opportunity to improve emergency care. *Pan Afr Med J.* 2016;24:294.
4. Gyedu A., Baah E. G., Boakye G., et al. Quality of referrals for elective surgery at a tertiary care hospital in a developing country: An opportunity for improving timely access to and cost-effectiveness of surgical care. *Int J Surg.* 2015;15C:74-78.
5. Gyedu A., Boakye G., Dally C. K., et al. Assessment of Barriers to Essential Surgical Care in Two Communities in the Upper West Region, Ghana. *J Health Care Poor Underserved.* 2017;28(1):175-90.
6. Japiong K. B., Asiamah G., Owusu-Dabo E., et al. Availability of resources for emergency care at a second-level hospital in Ghana: A mixed methods assessment. *African Journal of Emergency Medicine.* 2015.
7. Stewart B. T., Gyedu A., Tansley G., et al. Orthopaedic Trauma Care Capacity Assessment and Strategic Planning in Ghana: Mapping a Way Forward. *J Bone Joint Surg Am.* 2016;98(23):e104.
8. Tansley G., Stewart B., Zakariah A., et al. Population-level Spatial Access to Prehospital Care by the National

- Ambulance Service in Ghana. *Prehosp Emerg Care*. 2016;20(6):768-75.
9. Tansley G., Stewart B. T., Gyedu A., et al. The Correlation Between Poverty and Access to Essential Surgical Care in Ghana: A Geospatial Analysis. *World J Surg*. 2017;41(3):639-43.
 10. Zakariah A., Stewart B. T., Boateng E., et al. The Birth and Growth of the National Ambulance Service in Ghana. *Prehosp Disaster Med*. 2017;32(1):83-93.

Ancillary publications are available in the Appendix.

PUBLICATIONS EMANATING FROM THE WORK WITHIN THIS DISSERTATION

1. Chawla K. S., Rutkow L., Garber K., et al. Beyond a Moral Obligation: A Legal Framework for Emergency and Essential Surgical Care and Anesthesia. *World J Surg*. 2017.
2. Chawla S. S., Gupta S., Onchiri F. M., et al. Water availability at hospitals in low- and middle-income countries: implications for improving access to safe surgical care. *J Surg Res*. 2016;205(1):169-78.
3. Gardner A., Forson P. K., Oduro G., et al. Diagnostic accuracy of the Kampala Trauma Score using estimated Abbreviated Injury Scale scores and physician opinion. *Injury*. 2017;48(1):177-83.
4. Gyedu A., Abantanga F., Kyei I., et al. Changing Epidemiology of Intestinal Obstruction in Ghana: Signs of Increasing Surgical Capacity and an Aging Population. *Dig Surg*. 2015;32(5):389-96.
5. Gyedu A., Stewart B., Mock C., et al. Prevalence of preventable household risk factors for childhood burn injury in semi-urban Ghana: A population-based survey. *Burns*. 2016;42(3):633-8.

6. Hadler R. A., Chawla S., Stewart B. T., et al. Anesthesia Care Capacity at Health Facilities in 22 Low- and Middle-Income Countries. *World J Surg.* 2016.
7. Johnston L. E., Stewart B. T., Yangni-Angate H., et al. Peripheral Arterial Disease in Sub-Saharan Africa: A Review. *JAMA Surg.* 2016.
8. Reynolds T. A., Stewart B., Drewett I., et al. The Impact of Trauma Care Systems in Low- and Middle-Income Countries. *Annu Rev Public Health.* 2017.
9. Stewart B., Wong E., Papillon-Smith J., et al. An Analysis of Cesarean Section and Emergency Hernia Ratios as Markers of Surgical Capacity in Low-Income Countries Affected by Humanitarian Emergencies from 2008 - 2014 at Medecins sans Frontieres Operations Centre Brussels Projects. *PLoS Curr.* 2015;7.
10. Stewart B. T. Editorial Commentary on Bolkan et al. "The Surgical Workforce and Surgical Provider Productivity in Sierra Leone: A Countrywide Inventory". *World J Surg.* 2016.
11. Trelles M., Stewart B. T., Hemat H., et al. Averted health burden over 4 years at Medecins Sans Frontieres (MSF) Trauma Centre in Kunduz, Afghanistan, prior to its closure in 2015. *Surgery.* 2016;160(5):1414-21.
12. Garber K., Stewart B. T., Burkle F. M., Jr., et al. A Framework for a Battlefield Trauma System for Civilians. *Ann Surg.* 2018.
13. Stewart B. T. Commentary on 'A Consensus-Based Criterion Standard for the Requirement of a Trauma Team:' Low-Resource Setting Considerations. *World J Surg.* 2018.

CHAPTER 1 – INTRODUCTION AND SCOPE OF WORK

INTRODUCTION

Lack of access to safe, timely, and affordable surgical and trauma care (STC) is a public health problem worldwide, accounting for more than 10 million deaths and 15% of all disability-adjusted life years incurred annually.¹⁻³ The burden falls disproportionately on low- and middle-income countries (LMICs), which harbor 90% of these deaths.⁴

Despite incurring a larger burden than HIV, tuberculosis and malaria combined, preventing and treating surgical conditions and injuries have not been considered global health priorities.^{5, 6} Thus, STC has been under-financed and under-resourced in LMICs.⁷ Consequently, it is likely that better resourcing, planning and organization of STC could prevent a significant number of deaths and disabilities.⁸⁻¹⁰

SURGICAL AND TRAUMA CARE NEEDS ASSESSMENTS

The planning for, and organization of, STC development in LMICs requires baseline assessments of the availability of essential resources.^{7, 11} Needs assessments at both the individual hospital and national levels have taken the form of assessments of capacity (i.e., the physical and human resources required to perform a function).^{12, 13} The four most widely used assessment tools for STC in low-resource health systems are: i) World Health Organization (WHO) *Tool for Situational Analysis to Assess Emergency and Essential Surgical Care*; ii) WHO *Guidelines for Essential Trauma Care*; iii) *Surgeons Overseas Personnel, Infrastructure, Procedures, Equipment and Supplies Assessment*

(PIPES); and iv) Harvard Humanitarian Initiative surgical capacity assessment tool.^{11, 14-16}

Using these tools, nearly 30 STC capacity assessments have been performed in LMICs.⁷ Assessments have uniformly documented a lack of essential resources, particularly at district-level hospitals.^{7, 11, 12, 14, 15, 17-24} However, these assessment tools only examine resource inputs and do not systematically explore the causes of item deficiencies or integration into a broader emergency care system (ECS), thus limiting their utility.¹⁵ Further, with regard to the Donabedian model of quality improvement, capacity assessments have focused on structure (e.g., physical and human resources), and not processes (e.g., care delivery, use of protocols or policies) or outcomes (e.g., surgical cases performed, burden reduction).²⁵ As a result, few context-appropriate, actionable recommendations beyond resource improvements have been proposed.¹⁵

Immediately prior to starting the work outlined within this dissertation, a systematic examination of the causes of trauma care capacity deficiencies was undertaken.¹⁵ Shah et al performed an assessment of trauma care technology availability in Gujarat State, India. A lack of numerous specific items, many of which were low-cost, due to stock-outs and equipment breakdowns was common. However, locally manufactured items were fairly well supplied. The authors advocated for better procurement practices, supply chain management, training for use of existing resources, service contracts, and local repair capabilities. Similar deficiency cause analyses, useful for planning targeted health systems strengthening interventions, have not been performed, but provide a template for enhanced assessment of STC.

RAPID MEASURES OF SURGICAL AND TRAUMA CARE CAPACITY

Although capacity assessments have been the gold-standard starting block for STC development, they are time-consuming, relatively expensive, and resource intensive. Therefore, several groups have proposed metrics for assessing surgical or trauma care capacity more rapidly and without the need to perform a detailed capacity assessment. The proposed metrics are: i) cesarean section to all operations performed ratio; ii) emergency herniorrhaphy to all herniorrhaphies performed ratio; and iii) surgical care rate (number of operations performed in a theatre per 100,000 persons).²⁶⁻²⁸ While these metrics have been modeled or piloted in small studies, none have been rigorously validated or compared to one another.^{28, 29} Given that these metrics are being used to plan capacity improvement programs in several LMICs, a study that simultaneously assesses surgical and trauma care capacity and collects outcome (e.g., output) data required to validate these metrics was urgently needed.³⁰

Additionally, while the work within this dissertation was being planned and executed, three major movements were afoot. First, the World Health Assembly ratified Resolution 68.15, *Strengthening Emergency and Essential Surgical Care and Anesthesia (EESCA) as a Component of Universal Health Coverage*.³⁰ The resolution called for action by both the WHO and individual member states, including requests to:

- i. Carry out regular monitoring and evaluation of the EESCA capacity of healthcare facilities;
- ii. Collect and compile data on number, type, and indications of surgical procedures performed; and
- iii. Develop and implement surgical care and anesthesia policies to assure minimum standards for a skilled workforce.

Second, The Lancet Commission on Global Surgery presented its findings and recommendations for standardizing global surgery metrics, which included measurement of:^{31, 32}

- Geographic access to surgical care;
- Annual operation rate per 100,000 population; and
- And risk of impoverishing or catastrophic expenditure when surgery is required.

Geographic access and other metrics (e.g., perioperative mortality rate, waiting time to elective surgery) have been included in the WHO Global Reference List of 100 Core Health Indicators and in The World Bank health Development Indicators.^{33, 34}

Third, The World Bank published the Disease Control Priorities 3rd Edition included Essential Surgical Care.^{35, 36} This outlined several key aspects of 'essential surgery,' or a platform of highly cost-effective surgical interventions that would allow the most benefit to public health if universally delivered:

- Provision of essential surgical procedures would avert about 1.5 million deaths a year, or 6–7% of all avertable deaths in LMICs;
- Essential surgical procedures rank among the most cost effective of all health interventions;
- Substantial disparities remain in the safety and quality of surgical care; and
- The large burden of surgical conditions, cost-effectiveness of essential surgery, and strong public demand for surgical services suggest that universal coverage of essential surgery should be financed early on the path to universal health coverage.

Despite rapid adoption of these metrics and the essential surgery platform by stakeholders in global surgery and trauma care (e.g., ministries of health, academic institutions, non-governmental organizations, humanitarian actors), there had been little validation with prospectively collected data in LMICs.^{37, 38}

THE CAPACITY-QUALITY GAP

It has been postulated that capacity is directly associated to output (i.e., number of surgical or trauma-related procedures done per population). However, several reports and anecdotal evidence from Ghana suggest that there is wide variation in surgical output based on relatively similar and limited surgical capacity.^{17, 20, 39, 40} A dissociation between capacity and output would break from the fundamental assumptions underpinning capacity assessments and capacity building initiatives. Reasons for this potential uncoupling may be related to a multitude of other non-measured factors that might be important for improving output, such as differential population-level barriers to care, process components (e.g., protocols, policies), and system coordination. Although much has been written about these components in other fields and in high-income countries, little is known about how they interact with regard to STC or in LMIC health systems specifically.^{25, 41}

METRICS FOR ASSESSING QUALITY IN GLOBAL SURGERY AND TRAUMA CARE

Part of the challenge of assessing the quality of STC in LMICs has been a lack of context-appropriate metrics, particularly those for first- and second-level hospital use.^{36, 42} In high-income countries, such metrics are routinely collected in the form of audit filters.^{41, 43} Audit filters are descriptions of actions that should be performed, timeframes within which certain tests or procedures are provided, or outcomes that are expected in sick or injured persons.⁴³ However, existing filters rely on high-income healthcare system resources (e.g. computed tomography scan, timely access to surgical care).⁴¹ Consequently, they are inappropriate for LMIC hospitals, limiting the evaluation of processes of care and, thus, the development of quality improvement programs. A set of

context-appropriate audit filters may aid in baseline and serial assessment of processes of care.

In part for the aforementioned reasons, performing useful capacity assessments and building upon their results has been rare. Without models of successful capacity assessments, feasibly collected and validated metrics, and a toolkit for turning such data into a roadmap for development, STC will remain under-resourced and void of support from the global health community^{6, 44-46}. Without overcoming these important obstacles, substantial improvements cannot be expected.

THEORETICAL FRAMEWORK

Despite their shortcomings, STC capacity assessments have been invaluable for providing baseline data from which quality improvement programs could be benchmarked and building an evidence base for advocacy efforts.⁷ However, these assessments have relied on measures of resource, poorly characterized targets for intervention, neglected care processes and the healthcare system more broadly.^{7, 15} Further, the resource-based approach to evaluating capacity fails to consider knock-on improvements that arise from maximizing the utility of current resources (e.g. resource synergy, value innovation, local ingenuity) and integration and optimization of care processes within a system.

An assessment and quality improvement program that considers these potentials would be a valuable addition to surgical and trauma care development efforts, and can be understood through two frameworks.

The theory behind capacity assessments stems from the Donabedian model of health system strengthening and quality improvement, which considers a chain of three related

components that can be studied to gain insight into a given system:²⁵

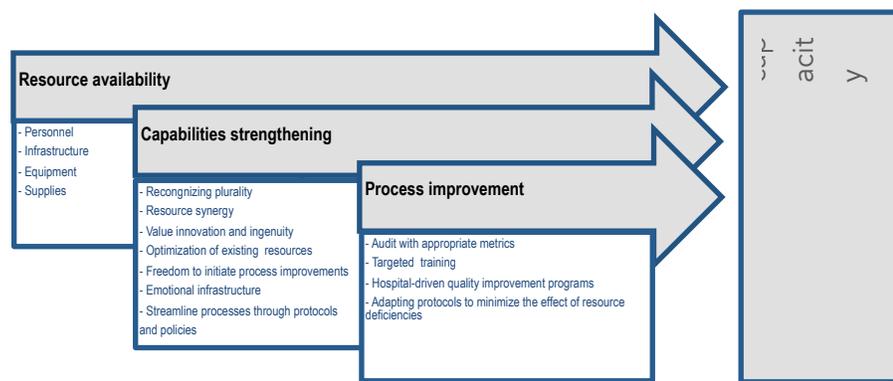
- Structure – the context in which care is delivered (e.g., infrastructure, staff, financing, equipment, supplies);
- Process – the transactions between patients and providers (e.g., adherence to protocols, care delivery, referral mechanisms);
- Outcome – the effects of healthcare on the status of patients and populations (e.g., output, morbidity, mortality, patient satisfaction).

Avedis Donabedian, a physician and health services researcher, designed this framework to allow assessment of the quality of clinical care in 1966.⁴⁷ Purposefully, the framework does not implicitly define quality, which allows its application to either narrow or broad systems (e.g., hospital versus national trauma system). Further, after the creation of the framework, Donabedian stressed that researchers must draw connections between the links in the chain (i.e., structure, process, outcome) in order to understand the system as a whole and effectively design interventions that improve quality across the continuum of care. However, he also appreciated the shortcomings of this framework, and noted that more than structures and processes were needed to achieve good outcomes. He posited: 'Systems awareness and systems design are important for health professionals, but are not enough. They are enabling mechanisms only. It is the ethical dimension of individuals that is essential to a system's success. Ultimately, the secret of quality is love.'⁴⁸

Opportunely, these potentials can be considered using the 'capabilities' approach.⁴⁹ Amartya Sen, a Noble Prize winning development economist, described the capabilities approach in the 1980s.⁵⁰ Sen proposed that welfare is more related to an individual's ability to transform available resources into valuable activities, so-called functionings, than simply the availability of

resources alone.⁵¹ Prior to this, welfare was measured by the presence or absence of resources and their differential distribution between population groups.⁵² While Sen did not reject the importance of equitable distribution of basic resources, he suggested that welfare should instead be measured by what one is able to do with the available resources.⁵⁰ Although the capability approach was designed to measure a society's economic welfare via individual's capabilities, the approach appears readily adaptable to the healthcare environment where hospitals are the 'healthcare system' is the society, processes of care are the 'functionings,' and staff are its 'individuals.' Therefore, in addition to establishing a foundational level of capacity from which essential care can be built, a broader examination of processes, human empowerment, and system integration is needed to truly characterize STC 'capability' a national level (Figure 1).

FIGURE 1. THEORETICAL FRAMEWORK FOR HOSPITAL-BASED TRAUMA CARE CAPACITY IMPROVEMENT AT THE DISTRICT-LEVEL.



CONCEPTUAL FRAMEWORKS

Improving the availability of personnel, infrastructure, equipment and supplies and the skills necessary to use them (i.e. capacity) at resource-limited hospitals improves STC.^{11,21} However, achieving good outcomes relies on the integration of capacity and processes, which is not currently assessed by existing capacity assessments. Further, all factors of Donabedian's model rely on patients, which are not central to current assessments and the obstacles they face are not factored into differences in outcome.

One might also consider that greater than expected improvements may occur with capacity building or other interventions rooted in the capability approach. These include interventions that empower hospital staff to develop local quality improvement programs (i.e. exercising freedom and option to improve circumstances with available resources) or determine ways in which individual hospitals can optimize existing resources (i.e. recognizing plurality, creating synergy, value innovation). Additionally, consideration of patient factors that affect STC (e.g., barriers to care, adherence) and system integration may lead to a more holistic assessment of STC capability and identification of targets for improvement.

This shift in the paradigm of developing capability instead of capacity will require metrics that reflect STC quality being provided at hospitals in tandem with assessment of available resources. By doing so, the effect of quality improvement programs can be adequately measured and useful recommendations defined.

TOWARDS A MORE HOLISTIC FRAMEWORK FOR STC

These two theoretical frameworks (i.e., Donabedian's model of quality improvement and Sen's capabilities approach) can be considered together and in terms of access to care (e.g., barriers

to care) and availability of care (e.g., capacity or capability, quality).

While there are many individual barriers to accessing care, they can be categorized into three domains:⁵³

- acceptability – the willingness and sociocultural appropriateness of care;
- affordability – indirect and direct costs of care; and
- accessibility – ability to navigate contact with the health system and structural challenges to reaching care.

Availability of care is similarly complex, as described above, and related to a host of factors beyond structure and process that can be broadly categorized into: governance and organization [e.g., leadership, incentivization schemes, emotional infrastructure (i.e., the motives, emotions and interactions of employees that helps organizations achieve excellence and effectiveness), policies and protocols]; financing; capacity and capabilities (e.g., infrastructure, physical and human resources, ability to function within an environment); data for quality and process improvement (e.g., data that allows monitoring, evaluation, and intervention); and preparedness for emergencies or disasters, or other shocks to the health system.

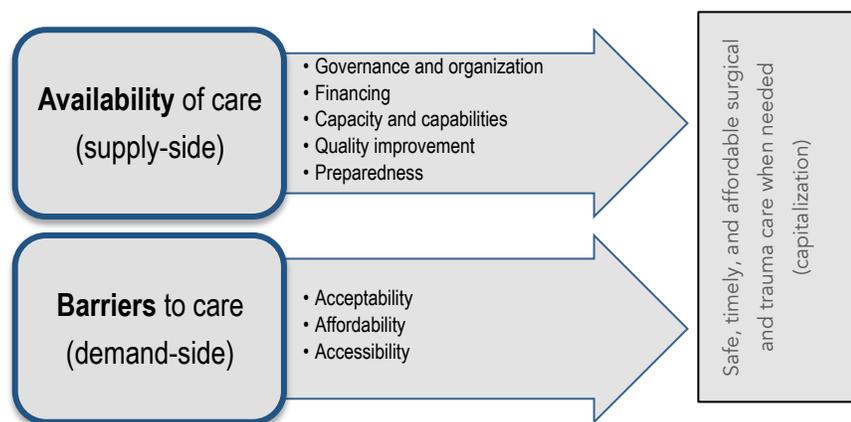
In reality, these two core issues (i.e., access or barriers to care, and availability of care) are related and can be described by a somewhat artificial distinction between the two to allow conceptualization of demand-side issues (i.e., access issues that are predominantly played out in the patients' environments) and supply-side issues (i.e., availability issues that are predominantly related to the health system).

Access to care and availability of care can be related in terms of capitalization. Capitalization rate is an economics concept used to describe the ratio of the outputs generated from an asset relative

to its capital cost.⁷ This concept has been broadened and recently highlighted in the sociology and education literatures to characterize issues around the latent human potential present in communities that does not get nourished, leading to underdevelopment of intelligence and skills amongst the poor or marginalized, as well as the relative costs associated with failing to capitalize on these 'assets'.⁸⁻¹¹

Applying capitalization to the healthcare context can be done by considering the intersection of demand-side (e.g., barriers to care seeking and access) and supply-side issues (e.g., availability of care) in the form of access to safe, timely, and affordable STC when needed. More specifically, capitalization can be considered the output generated from a set of inputs or costs for STC delivery (e.g., resources and functions; supply) and need (i.e., patient burden and access; demand); therefore, capitalization is the return on investment for minimizing barriers to care and optimizing care availability.

FIGURE 2. CONCEPTUAL FRAMEWORK FOR CAPITALIZATION OF SURGICAL AND TRAUMA CARE



PROBLEM STATEMENT

Capacity assessments and paradigms of healthcare development focus on what is deficient, not on why resources are not available or on what resources are available, and on the supply-side of care, not the complex interactions of both the supply- and demand side of care and the system more broadly. Additionally, capacity assessments neglect the 'functionings' of hospitals and staff required to turn available resources into quality care, such as processes and interaction with the STC system more broadly.

Given that a rapid, dramatic increase in funding and political will for STC development is unlikely to occur in most LMICs, understanding the relationship between capacity and output, defining useful and context-appropriate metrics, leveraging capabilities and synergy with existing resources, and evaluating STC within a broader system are important and urgently needed.

AIM

Assess demand- and supply-side STC factors that related to access, capacity and output in Ghana using both standard and novel metrics to inform a roadmap for STC system development.

OBJECTIVES

Objective 1. Determine the nationwide STC capacity of district-, regional-, and tertiary-level hospitals and identify resources and services that are deficient, as well as those that are available.

Objective 2. Identify contributing to specific resource and service deficiencies at each hospital to inform quality improvement interventions that aim to overcome resource and service non-availability and broaden capabilities.

- Objective 3.* Compare current to past STC capacity assessments in Ghana and identify factors contributing to improved availability, as well as to lower availability, so that these can further inform quality improvement interventions.
- Objective 4.* Explore the relationship between surgical capacity and surgical output.
- Objective 5.* Develop consensus-based and context-specific trauma care audit filters (i.e. data items that serve as proxies for quality trauma care and collective hospital capabilities) to monitor and evaluate process and quality improvement interventions.
- Objective 6.* Create and pilot a tool to systematically assess barriers to essential surgical care.
- Objective 7.* Determine population-level spatial access to essential STC.
- Objective 8.* Assess the STC system broadly and describe system integration and gaps, and create a roadmap for development with action priorities for the following domains: organization and governance, financing, data, quality improvement, scene care, transport and transfer, facility-based care, rehabilitation, and emergency and disaster preparedness.

CHAPTER 2 – STRATEGIC ASSESSMENT OF TRAUMA CARE CAPACITY IN GHANA

OBJECTIVES

Objective 1. Determine the nationwide STC capacity of district-, regional-, and tertiary-level hospitals and identify resources and services that are deficient, as well as those that are available.

Objective 2. Identify contributing to specific resource and service deficiencies at each hospital to inform quality improvement interventions that aim to overcome resource and service non-availability and broaden capabilities.

WORK IN CONTEXT

Based on prior assessments and anecdote, it was presumed that the STC capacity in Ghana was inadequate to meet the demands of Ghanaians with surgical conditions and injuries. However, the degree to which STC capacity was inadequate and the factors that contributed to resource and service deficiencies was not known. Therefore, this study was performed to describe STC capacity nationally and at each hospital level with a focus primarily on essential resources that should be available with sound planning and organization despite national resource constraints. We adapted an assessment tool previous used in Ghana so that serial comparison could be made. The tool was based on that provided with the WHO Emergency and Essential Surgical Care toolkit, but expanded to include resources and services deemed important by stakeholders at the Ghana Ministry of Health.

In addition to measures of capacity, the study was designed to identify factors that contributed to resource and service deficiencies, as well as successes. By doing so, potential solutions to inefficient aspects of health systems management and maladapted resources for trauma care in Ghana, as well as in other low- and middle-income countries (LMICs), could be identified.

CANDIDATE INVOLVEMENT

The candidate designed the study with collaborators within the Ghana Ministry of Health, sought relevant approvals with the assistance of mentoring Professors, collected data and performed key informant interviews at all hospitals, transcribed and managed the data, analyzed the data, and drafted the manuscript.

CO-AUTHOR INVOLVEMENT

RQ, PD, and CM reviewed the design of the study, assisted with introductions to get approvals for the study, and reviewed the manuscript. AG and JA assisted with data collection, reviewed the results and manuscript. All authors approved the final manuscript draft prior to publication.

ETHICS

Approvals from Kwame Nkrumah University of Science and Technology, the Ghana Health Service, and the University of Washington can be found in Appendix 2.1 – 2.4. Stellenbosch University reviewed all projects herein and found the ethics approvals appropriate. It was determined that the projects were exempt from further review. The letter from Stellenbosch University can be found in Appendix 3.5.

Strategic Assessment of Trauma Care Capacity in Ghana

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Abstract

Background This study aimed to assess availability of trauma care technology in Ghana. In addition, factors contributing to deficiencies were evaluated. By doing so, potential solutions to inefficient aspects of health systems management and maladapted technology for trauma care in low- and middle-income countries (LMICs) could be identified.

Methods Thirty-two items were selected from the World Health Organization's *Guidelines for Essential Trauma Care*. Direct inspection and structured interviews with administrative, clinical, and biomedical engineering staff were used to assess the challenges and successes of item availability at 40 purposively sampled district, regional, and tertiary hospitals.

Results Hospital assessments demonstrated marked deficiencies. Some of these were low cost, such as basic airway supplies, chest tubes, and cervical collars. Item non-availability resulted from several contributing factors, namely equipment absence, lack of training, frequent stock-outs, and technology breakage. A number of root causes for these factors were identified, including ineffective healthcare financing by way of untimely national insurance reimbursements, procurement and stock-management practices, and critical gaps in local biomedical engineering and trauma care training. Nonetheless, local examples of successfully overcoming deficiencies were identified (e.g., public–private partnering, ensuring company engineers trained technicians on-the-job during technology installation or servicing).

Conclusion While availability of several low-cost items could be better supplied by improvements in stock-management and procurement policies, there is a critical need for redress of the national insurance reimbursement system and trauma care training of district hospital staff. Further, developing local service and technical support capabilities is more and more pressing as technology plays an increasingly important role in LMIC healthcare systems.

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Introduction

With injuries resulting in more than 5 million deaths and significantly more disability annually, trauma care is increasingly recognized as a public health priority [1–4]. Low- and middle-income countries (LMICs) harbor the majority of the world's injuries and are least able to provide timely, effective care due, in part, to critical capacity deficiencies [5]. Subsequently, LMICs suffer disproportionately from this burden and urgently need trauma care capacity improvements [1].

Planning and organizing trauma care can substantially reduce mortality, disability, and preventable deaths [6–9]. An important element in these systems is the reliable availability of equipment and supplies and personnel trained to use them [10]. Therefore, the World Health Organization (WHO) published *Guidelines for Essential Trauma Care* (GETC) that defines minimum standards for human and physical resources necessary for managing injury.

Using GETC and similar assessment tools, studies have described surgical and trauma care capacity in LMICs [3, 5, 11–18]. These have documented deficiencies in infrastructure, resources, and training and have been important for building an evidence base for advocacy and capacity improvements. However, until recently, systematic examination of the causes of deficiencies has not been undertaken. Shah et al. performed an assessment of trauma care technology availability in Gujarat State, India [15]. A lack of numerous specific items, many of which were low cost, due to stock-outs and equipment breakdowns was common. However, locally manufactured items were fairly well supplied. The authors advocated for better procurement and stock-management, optimizing training for use of existing resources, and strengthening service contracts and local repair capabilities. Similar deficiency cause analyses, useful for planning targeted health systems strengthening interventions, have not been done in other LMICs.

This study aimed to assess the availability of technology-related resources for injury care in district-level, regional and tertiary hospitals in Ghana. It also sought to identify factors contributing to these deficiencies, as well as factors contributing to good availability. By doing so, we sought to identify potential solutions to limited operating budgets, inefficient aspects of health systems management and unsustainable or maladapted equipment and technology for trauma care.

Materials and methods

Setting

Ghana is a heavily indebted, LMIC in West Africa with a population of 26 million people and an annual per capita

income of US\$ 1760 [19]. Ghana has 10 regions divided into 110 districts. Most districts have several primary health centers (PHC) and a government or mission hospital that serves as a district (first-level) hospital. PHCs provide only basic public health and primary care services; therefore, they were not included in the study. District-level hospitals are staffed by medical officers and nurse anesthetists, and usually offer surgical services and have between 50 and 100 beds. Injuries requiring more complex care are referred to one of the regional or four teaching hospitals. In addition to medical officers and nurse anesthetists, regional hospitals are staffed by specialist providers (general and orthopedic surgeons) and contain between 100 and 400 beds. Surgical services offered at regional hospitals are broader in scope. There are four tertiary care hospitals in Ghana (one of which doubles as a regional hospital); all are affiliated with a medical school or residency program and offer more specialized care.

Sampling

All regional and tertiary facilities and a selection of district-level hospitals (totaling 40 facilities) were purposively sampled to represent hospitals most likely to care for injuries, the diversity of trauma care development, geography, and local socioeconomics. Permission and assistance in selecting hospitals using the aforementioned criteria were sought from each regional health directorate prior to hospital surveys. At least one district-level hospital in each region was selected by being

- in a populous area, near heavily trafficked roads likely to produce traffic injuries; *or*
- identified by the respective regional health directorate as caring for a higher injury volume than others within the region; *or*
- designated as a trauma hospital; *or*
- outside of an hour's transport to a regional or tertiary hospital.

One regional and one tertiary hospital declined participation.

Data collection

The WHO GETC lists 260 items of personnel and physical resources *essential* or *desirable* at different levels within a healthcare system. *Essential* items are considered most cost-effective and universally applicable, such as basic airway equipment and chest tubes. *Desirable* items add value but are not as cost-effective and more applicable in middle- or high-income or urban centers, such as computed tomography (CT) scans. The WHO GETC list covers the

breadth of human and physical resources and medications needed for trauma care. This study focused on 32 physical resource items (i.e., equipment, supplies, and medical technology). These were selected from the complete list by author consensus to represent resources for phases of the primary survey; laboratory and imaging diagnostics; definitive care; and rehabilitation. Although this study focused on physical resources, especially technology, the findings give important information about the national capacity for trauma care more broadly.

After leadership approval at each facility, each of the following staff members was asked to complete their respective part of the survey: surgeons, anesthetists, medical officers, administrators, accountants, procurement and logistic officers, technicians, biomedical engineers, and/or department in-charges. Each of the aforementioned staff members was identified and interviewed from the following departments: casualty, theater, surgical/trauma ward, critical care unit, laboratory, radiology, physiotherapy, procurement, accounts, and biomedical engineering. Some hospitals did not have a staff member in each of the aforementioned positions or all of the departments (e.g., not all district hospitals had a surgeon or biomedical engineer; not all regional hospitals had an intensive care unit). Nonetheless, the study team systematically asked to interview a staff member in each potential position and from each potential department to ensure no category of staff was overlooked. Staff members rated item availability as follows:

- 0—Absent, but should be present;
- 1—Inadequate, available to less than half of those who need it;
- 2—Partially adequate, available to more than half, but not to most who need it; or
- 3—Adequate, present, and readily available to almost everyone in need and used when needed.

For items rated 0–2, contributing factors were systematically asked and not considered mutually exclusive (except when items had never been present at a facility). These were, ‘The item or service has/is:

- Never been present;
- Present but broken and awaiting repairs;
- Present and staff able to use it, but when they go home at night or on the weekend no one is available to fill the position;
- No staff member trained in using the available item;
- Available, but lacks reagents or supplies;
- Necessary equipment or supplies out of stock or insufficient in number;
- Available, but only after pre-payment that prevents many from receiving the service or item; and/or

- Other, with explanation.’

Direct inspection of items was performed to corroborate ratings and further troubleshoot reason(s) for non-availability. Direct inspection included visually determining if the item was present or absent, examining it for useful availability (e.g., ensuring that the item worked, was not missing components/reagents/supplies, was not prohibitively expensive for patients) and evaluating why it was not available at times if rated less than 3 (e.g., stock-management practices, training deficiencies, and related to breakage). This was done for each item at every hospital. Factors contributing to good availability (i.e., successes, adaptations, and improvisations) were also recorded.

Data collection and analysis

Data were collected on paper forms and transcribed to Microsoft Excel (Redmond, Washington). Item availability rating (median and range) and factors contributing to non-availability (percent of hospitals reporting that factor for each item rated ≤ 2) were described using Stata v13 (College Station, Texas). Table 3 describes the percent of hospitals that reported each of the aforementioned factors contributing to specific item non-availability. Factors were not considered mutually exclusive except when items had never been present at a facility; therefore, some totals sum to more than 100 %. Individual percentages were shaded from light to dark gray corresponding to low and high figures, respectively.

Ethics

The Kwame Nkrumah University of Science and Technology Committee for Human Research and Publication Ethics and the University of Washington Institutional Review Board gave approval for the study. In addition, the Chief Director of the Ghana Ministry of Health, Director General of the Ghana Health Service, and respective Regional Health Directors granted research permission and facilitated hospital visits.

Results

Of the 40 facilities assessed, 29 were district-level (23 government and 6 mission), 8 were regional and 3 were tertiary hospitals. While specific trauma care items were often physically present at hospitals (i.e., rating >0 ; Table 1), they were frequently not available to most injured patients (i.e., rating <3 ; Table 2).

Table 1 Number and percent of sampled hospitals with the physical presence of trauma care items in Ghana

	Hospital type					
	District		Regional		Tertiary	
	n	(%)	n	(%)	n	(%)
Number assessed	29		8		3	
Airway						
Basic equipment ^a	22	(76)	7	(88)	3	(100)
Advanced equipment ^b	27	(93)	7	(88)	3	(100)
Breathing						
Oxygen supply	29	(100)	8	(100)	3	(100)
Chest tubes and water seal	6	(21)	2	(25)	3	(100)
Pulse oximetry	26	(90)	8	(100)	3	(100)
Bag-valve-mask	28	(97)	7	(88)	3	(100)
Mechanical ventilator	21	(72)	5	(63)	3	(100)
Circulation						
Blood transfusion ability	29	(100)	8	(100)	3	(100)
Electronic cardiac monitoring	9	(31)	5	(63)	3	(100)
Laboratory						
Hemoglobin	29	(100)	8	(100)	3	(100)
Electrolytes	13	(45)	5	(63)	2	(67)
Arterial blood gas, lactate	0	(0)	0	(0)	2	(67)
Imaging						
X-rays	20	(69)	7	(88)	3	(100)
Portable X-rays	5	(17)	2	(25)	2	(67)
FAST scan	8	(28)	3	(38)	2	(67)
CT scan	0	(0)	1	(13)	2	(67)
Angiography	0	(0)	1	(13)	1	(33)
General surgery						
Basic general surgery ^c	26	(90)	7	(88)	3	(100)
Major general surgery ^d	21	(72)	7	(88)	3	(100)
Vascular repair	3	(10)	1	(13)	2	(67)
Skin grafting	10	(34)	3	(38)	3	(100)
Extremity injury						
Closed reduction	23	(79)	7	(88)	3	(100)
Skin or skeletal traction	6	(21)	4	(50)	3	(100)
External fixation	2	(7)	3	(38)	3	(100)
Internal fixation	1	(3)	3	(38)	3	(100)
Prosthetics for amputees	1	(3)	0	(0)	1	(33)
Image intensification	4	(14)	4	(50)	3	(100)
Brain and spinal injury						
Basic neurosurgery ^e	1	(3)	0	(0)	2	(67)
Major neurosurgery	0	(0)	0	(0)	2	(67)
ICP monitoring	1	(3)	0	(0)	1	(33)

Table 1 continued

	Hospital type					
	District		Regional		Tertiary	
	n	(%)	n	(%)	n	(%)
Spine immobilization ^f	9	(31)	1	(13)	2	(67)
Spinal fixation	1	(3)	0	(0)	2	(67)

Items are only counted as present (i.e., rating 1–3, see text) or absent (i.e., rating 0, see text). Therefore, these figures do not consider items that were not functionally available (i.e., items that were broken, lacked reagents/supplies, did not have trained personnel to use them or were prohibitively expensive, etc)

FAST focused assessment with sonography for trauma, CT computed tomography, ICP intracranial pressure

^a Basic airway equipment—oral and nasal airways, suction pump

^b Advanced airway equipment—endotracheal tubes, laryngoscope

^c Basic surgery—wound debridement, ≤ 1 % total body surface area burn excision, digital amputation, surgical airway

^d Major surgery—neck exploration, exploratory laparotomy, major amputation

^e Basic neurosurgery—burr hole, treatment of open depressed skull fracture

^f Spine immobilization—cervical collar and back board

District-level hospitals

As indicated in Table 2, several resuscitation items were well supplied (median availability ratings of 2–3): airway equipment, oxygen supply, pulse oximetry, mechanical ventilators, and blood transfusion ability. However, ratings varied widely for these items between hospitals (0–3). For instance, ratings less than 2 for basic airway supplies were recorded at 34 % of hospitals and for blood transfusion capabilities at 31 % of hospitals. Some items were uniformly deficient (median rating 0), such as chest tubes, electronic cardiac monitoring, and electrolyte analysis. Cervical collars were not available at all at 69 % of district-level hospitals and only 14 % provided them consistently.

Outside of stationary X-rays (rating 2 or 3 at 62 % of hospitals), imaging capacity was under-resourced. Portable X-ray and focus assessment with sonography for trauma (FAST) scan were rarely available (median rating 0).

While definitive care services were generally not available, basic surgery (e.g., wound debridement, 1 % total body surface area burn excision, digital amputation, surgical airway) and closed reduction of fractures was available at district-level hospitals for most patients in need (median rating 3 and 2, respectively). Major general surgical or orthopedic procedures were not widely performed (median rating 1 or 0, respectively).

Regional hospitals

As indicated in Table 2, in general, regional hospitals had only marginally better ratings of item availability than district-level hospitals; exceptions include major surgery

(median rating 3) and skin or skeletal traction for fractures (median rating 2). Cervical collars (median rating 0), pulse oximetry (median rating 2), and mechanical ventilators (median rating 1) were less available than at district-level hospitals.

Stationary X-rays were completely absent at 12 % of hospitals and had ratings less than 3 at 75 % of hospitals. The median rating for portable X-ray and FAST capabilities was 0 (range 0–1 and 0–2, respectively).

Though with considerable disparity, most regional hospitals provided basic and major general surgical services (median rating 3, range 0–3 for both). Vascular repair or skin grafting capacity was rarely available.

Tertiary hospitals

Tertiary hospitals had fewer deficiencies among resuscitation items. However, mechanical ventilators, blood transfusion, electronic cardiac monitoring, and electrolyte and arterial blood gas laboratory capacity were not available at all tertiary facilities.

Imaging capacity, though greater than lower levels of care, was lacking for portable X-rays and CT scan (median rating 1, range 0–3 for both). FAST scan was consistently available in two of the three hospitals. Angiography was not present.

General surgical procedures were dependably available, though vascular repair, skin grafting, and basic neurosurgical procedures were not (rating range 0–3). Advanced orthopedic capacity was demonstrated by all tertiary hospitals (median rating 3); however, internal fixation and prosthetics for amputees were not widely available (rating range 0–2).

Table 2 Median availability ratings (and ranges) of trauma care items and services at hospitals in Ghana

	Median item availability rating (range)					
	District		Regional		Tertiary	
Number assessed	29		8		3	
Airway						
Basic equipment ^a	2	(0–3)	2	(0–3)	2	(2–3)
Advanced equipment ^b	3	(0–3)	3	(0–3)	3	
Breathing						
Oxygen supply	3	(1–3)	3	(2–3)	3	(2–3)
Chest tubes and water seal	0	(0–3)	0	(0–2)	3	
Pulse oximetry	3	(0–3)	2	(2–3)	3	
Bag-valve-mask	3	(0–3)	3	(0–3)	3	
Mechanical ventilator	2	(0–2)	1	(0–3)	3	(1–3)
Circulation						
Blood transfusion ability	2	(1–3)	2	(1–3)	2	(2–3)
Electronic cardiac monitoring	0	(0–2)	1	(0–2)	2	(1–2)
Laboratory						
Hemoglobin	3	(1–3)	3	(2–3)	3	
Electrolytes	0	(0–3)	1	(0–2)	2	(0–2)
Arterial blood gas, lactate	–	–	0		1	(0–2)
Imaging						
X-rays	2	(0–3)	2	(0–3)	2	(2–3)
Portable X-rays	0	(0–3)	0	(0–1)	1	(0–3)
FAST scan	0	(0–3)	0	(0–2)	3	(0–3)
CT scan	–	–	0		1	(0–3)
Angiography	–	–	0		0	
General surgery						
Basic general surgery ^c	3	(0–3)	3	(0–3)	3	
Major general surgery ^d	1	(0–3)	3	(0–3)	3	
Vascular repair	0	(0–2)	0	(0–2)	2	(0–2)
Skin grafting	0	(0–3)	0	(0–2)	2	(1–3)
Extremity injury						
Closed reduction	2	(0–3)	3	(0–3)	3	
Skin or skeletal traction	0	(0–3)	1.5	(0–3)	3	
External fixation	0	(0–3)	0	(0–3)	3	
Internal fixation	–	–	0	(0–1)	1	(1–2)
Prosthetics for amputees	0	(0–3)	0		0	(0–1)
Image intensification	0	(0–3)	1	(1–2)	3	
Brain and spinal injury						
Basic neurosurgery ^e	0	(0–1)	0		3	(0–3)
Major neurosurgery	–	–	0		3	(0–3)
ICP monitoring	–	–	0		0	(0–3)
Spine immobilization ^f	0	(0–3)	0	(0–1)	1	(0–3)
Spinal fixation	–	–	0		3	(0–3)

FAST focused assessment with sonography for trauma, CT computed tomography, ICP intracranial pressure

^a Basic airway equipment—oral and nasal airways, suction pump

^b Advanced airway equipment—endotracheal tubes, laryngoscope

^c Basic surgery—wound debridement, ≤ 1 % total body surface area burn excision, digital amputation, surgical airway

^d Major surgery—neck exploration, exploratory laparotomy, major amputation

^e Basic neurosurgery—burr hole, treatment of open depressed skull fracture

^f Spine immobilization—cervical collar and back board; Item availability was rated by hospital staff: 0—absent but should be present; 1—Inadequate, available to less than half of those who need it; 2—partially adequate, available to more than half, but not to most who need it; or 3—adequate, present and readily available to almost everyone in need and used when needed

Table 3 Percent of hospitals reporting a factor(s) contributing to specific item non-availability in Ghana

	Equipment absence	Broken	Personnel shortage	Lack of training	Lack of reagents/supplies	Stock-out, insufficient quantity	User fees necessary
District and mission hospitals (%)							
Basic airways ^a	13					45	
Suction		17				28	
Oxygen		10				28	
Pulse oximetry	7	21				24	
Chest tube	62			21		17	
Hemoglobin		14			24		
X-ray	24	45	14	4		10	
FAST scan	4		23	57		16	
Basic general surgery ^b	4		7	35			
Skin or skeletal traction	72			28			
Spine immobilization ^c	55					31	
Regional and tertiary hospitals (%)							
Basic airways	9					55	
Suction						46	
Pulse oximetry		27				36	
Chest tube	36			9		36	9
Mechanical ventilator	18	27				27	9
Electronic cardiac monitoring	27	18				55	
Arterial blood gas	73	9		9	9		
Hemoglobin		18	9				
Electrolytes		46	18		91		
X-ray	9	46	27			9	9
FAST scan			46	36		36	
CT scan	82		9				9
Major general surgery ^d			9	9			
External fixation	46			36		9	9
Internal fixation	46			9			45
Image intensification	36	18	10	36			
ICP measurement	91			9			
Prosthetics	91						9

FAST focused assessment with sonography for trauma, CT computed tomography, ICP intracranial pressure

^a Basic airway equipment—oral and nasal airways, suction pump

^b Basic general surgery—wound debridement, ≤ 1 % total body surface area burn excision, digital amputation, surgical airway

^c Spine immobilization—cervical collar and back board

^d Major surgery—neck exploration, exploratory laparotomy, major amputation; Contributing factors to item non-availability were systematically captured for all items rated ≤ 2 . Factors were not considered mutually exclusive except when items had never been present at a facility; therefore, some totals sum to more than 100 %. Individual percentages were shaded from light to dark gray corresponding to low and high figures, respectively

Factors contributing to item non-availability

The disparity between the relatively large proportion of hospitals with the physical presence of trauma care items detailed in Table 1 and the low availability ratings described by Table 2 are due to a number of factors. In

small hospitals, item absence (i.e., item has never been present), lack of trained personnel, insufficient/stock-out of supplies, and equipment breakage all contributed significantly to non-availability (Table 3). Non-drug consumables were often absent, such as basic airway supplies (13 % of hospitals did not have them at all), chest tubes

(62 %), and cervical collars (55 %). Frequent equipment breakage was compounded by lengthy service times (e.g., 4 hospitals reported being more than 6 months with inoperative X-ray machines). Several equipment items were not available due to insufficient quantity. For example, 16 % of hospitals reported non-availability of FAST scan in the resuscitation area due to only one ultrasound machine that strictly services the obstetrics department in a separate building. A number of hospitals did not perform FAST scan because of lack of training (57 % of hospitals) or trained personnel are not available on nights or weekends (35 % of hospitals) (Table 3).

Large hospitals faced similar challenges. Due, in part, to high patient volume, non-drug consumables were often the result of stock-outs (e.g., basic airways at 55 % of hospitals, chest tubes at 36 % of hospitals, orthopedic supplies, and implants). Functioning equipment was frequently spread thin across departments; non-availability of these items was due to insufficient quantity: suction (46 % of hospitals reported this as a contributing factor), pulse oximetry (36 %), mechanical ventilation (27 %), electronic cardiac monitoring (55 %), and FAST scan (36 %). Although lack of trained personnel was often recorded for orthopedic procedures, prosthetics were absent or required prohibitively expensive pre-payment and were not deficient due to a lack of trained physiotherapists (Table 3).

Financial

Every hospital was strained financially due to untimely national insurance reimbursement rates. Subsequently, facilities were unable to keep up with demand of non-drug consumables, have broken equipment repaired, or facilitate in-service trainings. To continue providing essential care, some hospitals thinned services for cost-minimization and all resorted to purchasing on credit. Anticipating late payment and currency depreciation, suppliers preemptively charged higher than usual prices for non-drug consumables. Consequently, necessary quantities of essential supplies frequently became unaffordable. Further, limited operating budgets did not allow infrastructure re-investment or saving for costly emergency repairs of broken technology. Insufficient internally generated funds (IGF) have become vital to sustaining essential services in the setting of untimely insurance reimbursements. However, non-insured services that contribute to IGF were not uniformly distributed between hospitals or regions leading to varying levels of essential service provision.

Engineering

Technology items were often inoperative, the result of non-durable technical consumables (e.g., broken plastic finger

clips on pulse oximeters, frayed cords from overuse) or equipment maladapted to cope with the dust, heat, and fluctuating power. There was also a lack of in-service training for new equipment and insufficient infrastructure investment (e.g., no networked viewers for digital X-ray systems) leading to sub-optimal usage. Lastly, there was minimal technical support for software faults, too few biomedical engineers for timely repair and regular service contracts were unaffordable, leading to lengthy breakage times (Fig. 1). Donated items were especially problematic. Equipment and technology items donated without regard to the Ghanaian context were almost uniformly not available over time (e.g., items with foreign language display/handbook or adapters; equipment without in-country reagent, supply, or replacement part sources or servicing capacity). Similarly, equipment for which government supplier and servicing contracts had expired was frequently not being used (e.g., chemistry analyzers).

Logistics

The procurement process was handwritten, required visual cataloging of consumables available at government medical stores (GMS; as opposed to print or online catalogs) and relied on paper forms. Subsequently, processing times were long and inflexible in cases of unexpected item shortages. Bedside inventory management was informal, without a low-level alert mechanism for items needing reordering. Second, GMS relied on hospital purchases. As a result, GMS were purchasing wholesale supplies on credit, thus frequently and unpredictably deficient in essential items. Obtaining authorization to purchase supplies in the open market (rather than at GMS) is a purposefully laborious process designed to minimize expensive open market purchases, but difficult to navigate in the time of regular GMS stock-outs. Lastly, open market suppliers did not reliably deliver items on time. Given the unpredictability of delivery, hospitals that placed infrequent, large orders to take advantage of bulk pricing often encountered stock-outs (Fig. 1).

Personnel

A lack of trained personnel commonly resulted in-service non-availability at night and during weekends. In addition, item non-availability was also related to knowledge and skill deficiencies among hospital staff. Essential items were often not used when indicated, despite being in stock, or were not requested for procurement (e.g., basic airways, chest tubes, cervical collars, and arterial blood gas tests). Technicians often refused to move mobile technology from their home departments (e.g., portable X-ray, radiology; ultrasound, and maternity) to the resuscitation area due to

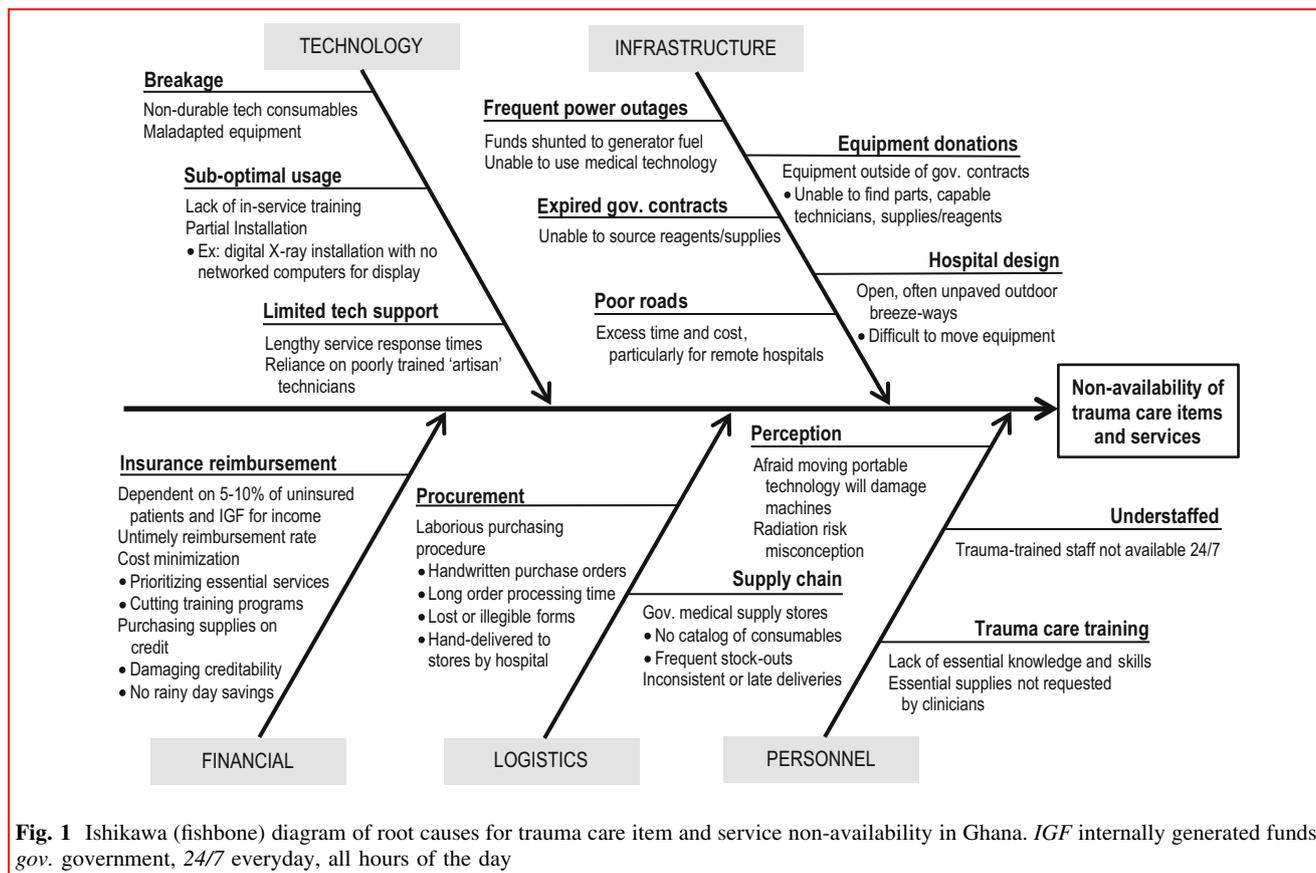


Fig. 1 Ishikawa (fishbone) diagram of root causes for trauma care item and service non-availability in Ghana. IGF internally generated funds, gov. government, 24/7 everyday, all hours of the day

fear of 'wear and tear.' Compounding this, there was a common misconception about unsafe radiation exposure outside of the X-ray department despite availability of lead aprons and adequate space for safe exposure in most casualty rooms (Fig. 1).

Externalities

Several contributing factors were beyond hospitals' control. Frequent power outages and inability to afford generator fuel led to non-availability of technology items, such as ventilators and cardiac monitors. The cost of service delivery was increased, occasionally to the point of non-availability, due to poor roads, particularly for remote hospitals (Fig. 1).

Success stories

Despite the numerous factors contributing to deficiencies, many hospitals reported implementing successful methods to overcome item or service non-availability. Some of the examples from Table 4 are instructive. Several hospitals were

able to partially alleviate the effects of untimely insurance reimbursements by partnering with businesses or non-governmental organizations, ensuring locum surgeon cost-effectiveness with performance-based payments or expanding non-insured services (e.g., mortuary and outpatient physiotherapy). To relieve technical support deficiencies, two hospitals ensured that company biomedical engineers provided on-the-job-training to local technicians when they came to install or service equipment. Similarly, department in-charges who ensured that veteran staff taught and overlapped inexperienced staff's shifts mitigated deficiencies resulting from high-staff turnover and the complexity of operating some technology items. This was particularly successful with ventilator and cardiac monitor use.

Discussion

This study aimed to identify health systems management (i.e., procurement, supply chain management, financing, training) and product development (i.e., developing more durable medical equipment) priorities for strengthening

Table 4 Challenges and successes with the delivery of trauma care observed in or reported by hospitals in Ghana

	Specific challenges	Observed and reported successes
Financial	Locum salaries were expensive and hospital was unable to pay ancillary staff such as drivers, maintenance, security personnel	Changed locum surgeons from salaried to performance-based payments to ensure their cost-effectiveness
	Untimely insurance reimbursement rates; reliance on internally generated funds	Selling oxygen if on-site condenser, clean water sachets if on-site purifier, non-essential provisions Opened medical supply store Renting conference rooms Expanding non-insured services such as the mortuary, public catering, physiotherapy, microbiology and hormone tests, occupational and school/sport physicals
	No reserve funds for unexpected infrastructure emergencies or expensive repairs of broken technology	Developed endowment fund where patrons contribute standard very small amounts voluntarily (and independent of care), fund is matched by local business and invested Partner with NGOs and businesses to help with infrastructure re-investment and purchasing medical technology
	Fixed tariffs and insurance reimbursement rates at all government facilities despite geography/road infrastructure do not account for local variation in supply or service delivery costs	
Procurement, logistics, and infrastructure	Suppliers rate-adjust (speculate) after supplies purchased on credit and before payment depending on Cedis value, greatly increasing cost of non-drug consumables in the long run	Created a contract detailing terms of payment and penalties when using credit up front in the open market when government stores are insufficient Established standard rate-adjustment clauses for interval depreciation of Cedis
	Oxygen plant can be local or up to 570 km on poor roads; delivery expensive (one hospital paid ~US\$ 1000 per week for driver, fuel and oxygen from non-local plant); subsequently, stock-outs common	Invested in on-site oxygen condenser or back-up oxygen concentrator when stock-out Negotiated cylinder transport with public transportation
	Power outages often affect clinical care	Bought rechargeable theater lights and battery packs (UPS) to run technology Timed turning generator off (fuel too expensive) outside of peak operating hours
	Single operating theater often occupied by other emergencies (cesarean sections) when severe trauma arrives	Renovated consultation room into basic procedure room with anesthesia capacity for chest tubes, DPLs, wound washouts and debridement to reduce the need for theater time
	Dust often clogs hydraulics/mechanics in operating and X-ray tables	Added air conditioner in order to keep windows closed in theater and X-ray Budgeted routine service to avoid unexpected emergency breakage
	Frequent equipment malfunction or reagent stock-outs	Hematology capacity was redundant with semi-automated and manual equipment at many hospitals to prevent inability to result hemoglobin Calculated average monthly reagent use and scheduled shipments with supplier
	Lack of numerous non-drug consumables	Improvised with underwater-seal made from drinking water bottles; towels/cotton rolls for cervical collars; NG tubes for chest tubes
Specific item non-availability	Hospitals designed with open, often unpaved walkways; staff fearful about letting portable X-ray and ultrasound machines leave radiology or maternity buildings making them unavailable in the ER or theater	Purchased mini-ultrasound for FAST scans Kept portable X-ray in ER but used processor in X-ray department

Table 4 continued

	Specific challenges	Observed and reported successes
	Three hospitals had MRIs but no CTs and portable X-rays were often not moved from X-ray department for staff fear of radiation exposure	Educated providers about low risks to radiation exposure with simple precautions Created resuscitation area with 'safe radiation space'
	Stock-outs, if not due to inability to afford replacement, were often due to inconsistent or late deliveries	Planned for late delivery by ordering items more frequently to avoid both stock-outs and surplus
	Despite being new, digital X-ray equipment problems often result in non-availability	Invested in networking ahead of time so that resulting images didn't rely on costly printing or manual carrying of USB drives/CDs from department to department
	No catalog of non-drug consumables available at regional or central stores; hospitals must use truck, driver, fuel to inventory government stores prior to determining what can be purchased there versus the open market	
	Lack of recurrent voluntary blood donors	Mobilized of recurrent donors with calling cards, scheduled email and phone/SMS reminders Radio blood donation education campaigns Bleeding teams screened blood after returning to hospitals to avoid HIV screening stigma in the community
	Blood pool often low	Purchased truck and hired part-time mobilizer to increase blood pool
	Schools are major source of blood donors, when on vacation, outages are common	Planned donations through community organizations (churches, mosques) during school holidays
Training	High-staff turnover and lack of training made medical technology less effective	Overlapped experienced and inexperienced staff in departments to become familiar with equipment and technology
	Lack of skilled biomedical engineers and abundance of 'artisan' technicians with varied training and abilities	When biomedical engineers came to service broken equipment, they taught local 'artisan' technicians how to troubleshoot and repair troublesome equipment
Donated equipment	Technology/equipment with displays in foreign languages; No parts, adapters, reagents available in country	Discussed with donors prior to donating equipment to ensure local usefulness and servicing availability

Cedis Ghanaian currency, *NGO* non-governmental organization, *UPS* uninterrupted power supply, *DPL* diagnostic peritoneal lavage, *ER* emergency room, *MRI* magnetic resonance imaging, *CT* computed tomography, *NG* nasogastric, *FAST* focused assessment with sonography for trauma, *SMS* short messaging service (also text messages)

availability of trauma care in Ghana and other LMICs. Hospital assessments demonstrated marked essential item deficiencies resulting from equipment absence, lack of training, frequent stock-outs, and engineering issues.

One of the main contributing factors to deficiencies was financial, especially due to delayed payments from the National Health Insurance Scheme. In 2003, Ghana passed the National Health Insurance Act to ensure essential care for its citizens. Despite early success, total timely reimbursement rates are now low due to increasing reliance on a narrow tax base, large informal populations, and significant healthcare utilization [20–22]. Such challenges are significantly hindering hospitals' ability to purchase essential items, provide training, and afford repairs. Reimbursement mechanisms require thoughtful redress by insurance policy planners.

Capacity bought from vertical, disease-specific investment (e.g., hemoglobin testing, blood banking and obstetric ultrasonography, for HIV and maternal health programs)

was significantly more available than resources for trauma care. Though vertical programs have been relatively successful for disease-specific interventions and occasionally provide broader benefits (e.g., increased blood transfusion capabilities for trauma and other causes of hemorrhage from maternal health initiatives), they may channel resources away from other pressing public health dilemmas, like trauma care [23, 24]. Investment in timely, coordinated, essential trauma care would improve capacity to care for a host of other conditions that benefit from pre-hospital, emergency, surgical, and rehabilitative care. Therefore, funding dedicated to trauma care capacity development should be prioritized [11, 24].

When not due to insufficient funding, stock-outs resulted from inventory management and procurement process challenges, common in sub-Saharan Africa [25, 26]. Establishing bedside low-supply alert mechanisms and real-time catalogs of GMS may reduce the number and period of stock-outs. *SMS for Life*, a public-private

partnership that uses text-messaging to flag low-stocks of anti-malarial drugs, was able to reduce stock-outs from 79 to 26 % at health centers in rural Tanzania [27]. Given *SMS for Life* costs less than US\$ 80 per facility per year, similar systems for non-drug consumables could be readily implemented in LMIC health systems [28].

Equipment donated without regard for affordable reagent, supply or replacement part availability, personnel trained in its use and capable in-country technical support for installation, maintenance, and repair gave perception of capacity improvement, but have wasted scarce resources and distracted health systems from systematic development [29, 30]. Health systems in need of equipment could create a standard list of needed items and suppliers that are more appropriate for the context in which they work [29].

Our study did find systemic engineering-related issues, such as digital X-ray systems without networked computers and broken technology without capable technicians to repair it. However, such engineering problems were less than those reported in a similar study in Gujarat State, India [15]. As Ghana and other LMICs overcome the financial and human resource barriers to providing timely trauma care, ensuring symmetric infrastructure, in-service training, biomedical engineering, and information technology capacity improvements will avoid further sub-optimal usage of medical technology. In addition, maladapted equipment (e.g., pulse oximeter finger clips) could be re-designed to improve durability, and technical consumables (e.g., cardiac monitor electrodes and diathermy pads) could be supplied as non-disposables to reduce non-availability.

Several items were deficient due to inadequate training, including use of chest tubes, FAST scan, and skin or skeletal traction. There is clearly a role for improved training, especially in the form of increased availability of continuing education courses. Such training has been documented to improve care of the injured at an affordable cost [31]. For example, *Village University* trauma care courses for lay providers and district hospital staff in Iraq and Cambodia reduced injury-related mortality by 75 % in only over 5 years [32, 33]. District hospitals in Vietnam previously reported trauma care deficiencies consistent with those demonstrated in this study [34]. With in-service training of nurses and doctors and greater attention to planning for trauma care, appropriate use of basic airways, chest tubes, and cervical collars was found to be significantly improved by evaluations one and 3 years [35, 36].

This study had several limitations that should be considered before drawing conclusions. The rating scheme (0–3) was somewhat subjective. In an attempt to strengthen its validity, key informants from several departments that interact with the same item (e.g., X-ray—emergency room doctors, emergency room nurses, surgeons, nurse anesthetists, X-ray technicians, and biomedical engineers) were

asked about its availability to triangulate responses. Further, direct observation of equipment and supplies was performed. One regional and one tertiary hospital in a highly populated area declined participation. Their resource availability may be more or less than other facilities within the same healthcare level. Attempts were made to understand the root causes of deficiencies; however, there were many external causes beyond the hospital level that we were unable to examine. Despite aforementioned limitations, these results provide a more useful assessment of trauma care capacity than previously reported in sub-Saharan Africa. They allow reasonable conclusions to be drawn about ways to improve the reliability of trauma care items and services.

Conclusion

This study identified a number of successes and problems with the availability of trauma care technology in Ghana. Item availability could be improved, both affordably and reliably, by better organization and planning, such as improvements in stock-management and procurement policies, particularly for essential low-cost items; optimizing use of current and future medical technology by training clinical staff and the technical workforce; ensuring constant service and supply contracts at the regional and national level; and providing continuing education for district and regional staff (doctors, nurses, and technicians) to reinforce the fundamentals of trauma care, which will avert mismatch of human and physical resources. Most of all, there is a critical need for redress of the national insurance reimbursement mechanism so that hospitals are invariably able to purchase supplies and equipment essential for trauma care. Regarding product development, creating or promoting more durable or reusable technical consumables (e.g., pulse oximetry finger clips, diathermy pads, and cardiac monitor electrodes) would reduce item non-availability in the high-use district hospital setting. Developing local service and technical support capability was highlighted as a priority to avoid long periods of equipment breakage; this is becoming more and more pressing as technology plays an increasingly important part in LMIC healthcare systems.

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Compliance with Ethical Standards

Conflict of interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

- Lozano R, Naghavi M, Foreman K et al (2012) Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 380:2095–2128
- Mock C (2013) Confronting the global burden of surgical disease. *World J Surg* 37:1457–1459. doi:10.1007/s00268-013-2102-x
- Ozgediz D, Jamison D, Cherian M et al (2008) The burden of surgical conditions and access to surgical care in low- and middle-income countries. *Bull World Health Organ* 86:646–647
- Stewart B, Khanduri P, McCord C et al (2014) Global disease burden of conditions requiring emergency surgery. *Br J Surg* 101:e9–e22
- Wong EG, Gupta S, Deckelbaum DL et al (2014) Prioritizing injury care: a review of trauma capacity in low and middle-income countries. *J Surg Res* 193(1):217–222
- Jurkovich GJ, Mock C (1999) Systematic review of trauma system effectiveness based on registry comparisons. *J Trauma* 47:S46–S55
- Mann NC, Mullins RJ, MacKenzie EJ et al (1999) Systematic review of published evidence regarding trauma system effectiveness. *J Trauma* 47:S25–S33
- Nathens AB, Jurkovich GJ, Cummings P et al (2000) The effect of organized systems of trauma care on motor vehicle crash mortality. *JAMA* 283:1990–1994
- Nathens AB, Jurkovich GJ, Rivara FP et al (2000) Effectiveness of state trauma systems in reducing injury-related mortality: a national evaluation. *J Trauma* 48:25–30; (discussion 30–21)
- Kushner AL (2014) A proposed matrix for planning global surgery interventions. *World J Surg* 38(12):3039–3040. doi:10.1007/s00268-014-2748-z
- LeBrun DG, Chackungal S, Chao TE et al (2014) Prioritizing essential surgery and safe anesthesia for the post-2015 development agenda: operative capacities of 78 district hospitals in 7 low- and middle-income countries. *Surgery* 155:365–373
- Gupta S, Wong E, Mahmood U et al (2014) Burn management capacity in low and middle-income countries: a systematic review of 458 hospitals across 14 countries. *Int J Surg* 12(10):1070–1073
- Ologunde R, Vogel JP, Cherian MN et al (2014) Assessment of cesarean delivery availability in 26 low- and middle-income countries: a cross-sectional study. *Am J Obstet Gynecol* 211(5):504e1
- Kingham TP, Kamara TB, Cherian MN et al (2009) Quantifying surgical capacity in Sierra Leone: a guide for improving surgical care. *Arch Surg* 144:122–127; (discussion 128)
- Shah MT, Joshipura M, Singleton J et al (2014) Assessment of the availability of technology for trauma care in India. *World J Surg* 39(2):363–372. doi:10.1007/s00268-014-2805-7
- Knowlton LM, Chackungal S, Dahn B et al (2013) Liberian surgical and anesthesia infrastructure: a survey of county hospitals. *World J Surg* 37:721–729. doi:10.1007/s00268-013-1903-2
- Linden AF, Sekidde FS, Galukande M et al (2012) Challenges of surgery in developing countries: a survey of surgical and anesthesia capacity in Uganda's public hospitals. *World J Surg* 36:1056–1065. doi:10.1007/s00268-012-1482-7
- Notrica MR, Evans FM, Knowlton LM et al (2011) Rwandan surgical and anesthesia infrastructure: a survey of district hospitals. *World J Surg* 35:1770–1780. doi:10.1007/s00268-011-1125-4
- CIA World Factbook: Ghana (2014) United States Central Intelligence Agency, Washington, D.C. <http://www.ciaworldfactbook.us/africa/ghana.html>. Accessed 12 Apr 2015
- Sodzi-Tettey S, Aikins M, Awoonor-Williams JK et al (2012) Challenges in provider payment under the Ghana National Health Insurance Scheme: a case study of claims management in two districts. *Ghana Med J* 46:189–199
- Lagomarsino G, Garabrant A, Adyas A et al (2012) Moving towards universal health coverage: health insurance reforms in nine developing countries in Africa and Asia. *Lancet* 380:933–943
- McIntyre D, Garshong B, Mtei G et al (2008) Beyond fragmentation and towards universal coverage: insights from Ghana, South Africa and the United Republic of Tanzania. *Bull World Health Organ* 86:871–876
- Ooms G, Van Damme W, Baker BK et al (2008) The 'diagonal' approach to Global Fund financing: a cure for the broader malaise of health systems? *Global Health* 4:6
- Patel PB, Hoyler M, Maine R et al (2012) An opportunity for diagonal development in global surgery: cleft lip and palate care in resource-limited settings. *Plast Surg Int* 2012:892437
- Pasquet A, Messou E, Gabillard D et al (2010) Impact of drug stock-outs on death and retention to care among HIV-infected patients on combination antiretroviral therapy in Abidjan, Cote d'Ivoire. *PLoS One* 5:e13414
- Watsierah CA, Ouma C (2014) Access to artemisinin-based combination therapy (ACT) and quinine in malaria holoendemic regions of western Kenya. *Malar J* 13:290
- Barrington J, Wereko-Brobby O, Ward P et al (2010) SMS for Life: a pilot project to improve anti-malarial drug supply management in rural Tanzania using standard technology. *Malar J* 9:298
- Githinji S, Kigen S, Memusi D et al (2013) Reducing stock-outs of life saving malaria commodities using mobile phone text-messaging: SMS for life study in Kenya. *PLoS One* 8:e54066
- Cordero I, Murray N, Nkumbe HE (2010) Donations: how to ensure you really benefit. *Community Eye Health* 23:32–33
- Gatrad AR, Gatrad S, Gatrad A (2007) Equipment donation to developing countries. *Anaesthesia* 62(Suppl 1):90–95
- Mock CN, Quansah R, Addae-Mensah L et al (2005) The development of continuing education for trauma care in an African nation. *Injury* 36:725–732
- Husum H, Gilbert M, Wisborg T et al (2003) Rural prehospital trauma systems improve trauma outcome in low-income countries: a prospective study from North Iraq and Cambodia. *J Trauma* 54:1188–1196
- Van Heng Y, Davoung C, Husum H (2008) Non-doctors as trauma surgeons? A controlled study of trauma training for non-graduate surgeons in rural Cambodia. *Prehospital Disaster Med* 23:483–489; (discussion 490–481)
- Mock C, Nguyen S, Quansah R et al (2006) Evaluation of trauma care capabilities in four countries using the WHO-IATSI Guidelines for Essential Trauma Care. *World J Surg* 30:946–956. doi:10.1007/s00268-005-0768-4
- Son NT, Mock C (2006) Improvements in trauma care capabilities in Vietnam through use of the WHO-IATSI Guidelines for Essential Trauma Care. *Int J Inj Control Saf Promot* 13:125–127
- Son NT, Thu NH, Tu NT et al (2007) Assessment of the status of resources for essential trauma care in Hanoi and Khanh Hoa, Vietnam. *Injury* 38:1014–1022

NEXT STEPS

The work in this chapter demonstrated that the availability of several essential and low-cost items could be better supplied by improvements in stock management and procurement policies. Additionally, it was determined that there is a critical need for redress of the national insurance reimbursement system and trauma care training of district hospital staff. Lastly, developing local service and technical support capabilities seemed to be pressing given that technology played an increasingly important role in the healthcare system.

The findings were presented to the Ministry of Health, Ghana Health Service, Christian Health Association of Ghana, and each regional health directorate. The health leadership within each of these agencies planned to use the information as part of a continuous quality improvement program to improve essential services nationwide. Specifically, the leadership acknowledged the importance of improved stock management practices, re-examining the supply chain for trauma care resources, and organizing training for providers who provide care for the injured.

The Ministry of Health had spent a lot of energy and money on capacity building for essential services and improving financial risk pooling in the decade prior. In order to determine the effectiveness of these efforts related to trauma care, a comparison between the assessment described in this chapter and a prior capacity assessment performed 10 years prior was needed.

CHAPTER 3 – SERIAL ASSESSMENT OF TRAUMA CARE CAPACITY IN GHANA IN 2004 AND 2014

OBJECTIVES

Objective 3. Compare the results from Objectives 1 and 2 with a STC capacity assessment done in Ghana in 2004 to identify factors contributing to improved availability, as well as to lower availability, so that these can further inform quality improvement interventions.

WORK IN CONTEXT

The comparison of the availability of trauma care resources in Ghana between 2004 and 2014 demonstrated evidence of significant improvement. However, critical deficiencies remain and require redress in order to improve care for the injured. According to the findings, areas where progress can result in significant benefits include prioritizing availability of essential trauma resources, training in their use and better stock management.

Trauma care capacity assessments in developing countries have generated evidence to support advocacy, detailed baseline capabilities, and informed targeted interventions. However, serial assessments to determine the effect of capacity improvements or changes over time have rarely been performed. This study aimed to determine not only differences in trauma care capacity over time, but also if capacity assessments could be particularly useful when used in serial for measurements of structure improvements over time. In immature trauma and health care systems broadly, measurements of process or outcome metrics alone may not provide sufficient or actionable information.

CANDIDATE INVOLVEMENT

The candidate designed the study, sought relevant approvals with the assistance of mentoring Professors, collected data and performed key informant interviews at all hospitals, transcribed and managed the data, analyzed the data, and drafted the manuscript.

CO-AUTHOR INVOLVEMENT

RQ, PD, FA, and CM reviewed the design of the study, assisted with introductions to get approvals for the study, and reviewed the manuscript. AG, GB and JA assisted with data collection, reviewed the results and manuscript. All authors approved the final manuscript draft prior to publication.

ETHICS

Approvals from Kwame Nkrumah University of Science and Technology, the Ghana Health Service, and the University of Washington can be found in Appendix 2.1 – 2.4. These are the same approvals required for Objectives 1 and 2. Stellenbosch University reviewed of all projects herein and found the ethics approvals appropriate. It was determined that the projects were exempt from further review. The letter from Stellenbosch University can be found in Appendix 3.5.

Original Investigation

Serial Assessment of Trauma Care Capacity in Ghana in 2004 and 2014

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 Invited Commentary

IMPORTANCE Trauma care capacity assessments in developing countries have generated evidence to support advocacy, detailed baseline capabilities, and informed targeted interventions. However, serial assessments to determine the effect of capacity improvements or changes over time have rarely been performed.

OBJECTIVE To compare the availability of trauma care resources in Ghana between 2004 and 2014 to assess the effects of a decade of change in the trauma care landscape and derive recommendations for improvements.

DESIGN, SETTING, AND PARTICIPANTS Capacity assessments were performed using direct inspection and structured interviews derived from the World Health Organization's *Guidelines for Essential Trauma Care*. In Ghana, 10 hospitals in 2004 and 32 hospitals in 2014 were purposively sampled to represent those most likely to care for injuries. Clinical staff, administrators, logistic/procurement officers, and technicians/biomedical engineers who interacted, directly or indirectly, with trauma care resources were interviewed at each hospital.

MAIN OUTCOMES AND MEASURES Availability of items for trauma care was rated from 0 (complete absence) to 3 (fully available). Factors contributing to deficiency in 2014 were determined for items rated lower than 3. Each item rated lower than 3 at a specific hospital was defined as a hospital-item deficiency. Scores for total number of hospital-item deficiencies were derived for each contributing factor.

RESULTS There were significant improvements in mean ratings for trauma care resources: district-level (smaller) hospitals had a mean rating of 0.8 for all items in 2004 vs 1.3 in 2014 ($P = .002$); regional (larger) hospitals had a mean rating of 1.1 in 2004 vs 1.4 in 2014 ($P = .01$). However, a number of critical deficiencies remain (eg, chest tubes, diagnostics, and orthopedic and neurosurgical care; mean ratings ≤ 2). Leading contributing factors were item absence (503 hospital-item deficiencies), lack of training (335 hospital-item deficiencies), and stockout of consumables (137 hospital-item deficiencies).

CONCLUSIONS AND RELEVANCE There has been significant improvement in trauma care capacity during the past decade in Ghana; however, critical deficiencies remain and require urgent redress to avert preventable death and disability. Serial capacity assessment is a valuable tool for monitoring efforts to strengthen trauma care systems, identifying what has been successful, and highlighting needs.

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Trauma has become increasingly recognized as a leading cause of death and disability.¹⁻³ To benchmark capabilities, trauma care capacity assessments in low- and middle-income countries (LMICs) have been performed. Additionally, these assessments have generated evidence to support advocacy and identified specific deficits to inform targeted interventions.⁴

Despite more than 20 assessments, only 2 countries have compared repeated assessments with baseline capacity to determine the effect of trauma care advocacy or interventions over time.⁴⁻⁸ Serial assessment after 3 years of surgical capacity expansions in Sierra Leone demonstrated significant improvements at nearly all of the 10 hospitals reassessed.^{4,5} In Hanoi, Vietnam, initial assessment of trauma care occurred in 2002. After identifying deficiencies in training and physical resources, targeted interventions were implemented. One year later, 9 of 13 items at district-level hospitals and 7 of 13 items at city hospitals were more often available and used than before the interventions.⁸ Serial capacity assessments are useful for quantifying the effect of health systems, strengthening efforts in LMICs, and informing the way forward.^{9,10}

In 2004, a systematic assessment of trauma care capacity was performed in Ghana using the World Health Organization's *Guidelines for Essential Trauma Care*.^{3,11} Since then, Ghana witnessed the birth and growth of a national ambulance service, implementation and maturation of the National Health Insurance Scheme, creation and dissolution of a trauma care continuing education course, formation of an emergency medicine training program, and rapid urbanization with concomitant increases in road injury.¹²⁻¹⁶ The summative effect of these exposures on national trauma care capacity is unknown.

This study aimed to compare the availability of trauma care services and the resources necessary to provide them in district-level and regional hospitals in Ghana between 2004 and 2014. By doing so, the effects of a decade of change in Ghana's trauma care landscape can be assessed and potential interventions defined.

Methods

Setting

Ghana is a heavily indebted, lower-middle-income country in West Africa with a population of nearly 26 million people.¹⁷ From 2004 to 2014, life expectancy at birth increased from 57 to 61 years. This gain came in part from improved health care development evidenced by a tripling of government health expenditure per capita and creation of the National Health Insurance Scheme, which covers emergency care.^{17,18} However, the government health expenditure per capita as a percentage of gross domestic product has decreased from 6.1% to 4.5%. Ghana has also witnessed a dramatic increase in motor vehicle ownership, heralding the potential for a greater incidence of road traffic injuries (Table 1).¹⁹

Sampling

For both assessments, district-level hospitals were sampled to represent those most likely to care for injuries, the diversity

Table 1. Ghana's Development Indicators in 2004 and 2014

Development Indicator	2004	2014
Population, No.	20 840 000	25 900 000
Urban population, %	47	53
Life expectancy at birth, y	57	61
GDP per capita, \$	426	1850
Government health expenditure per capita		
\$	26	83
GDP, %	6.1	4.5
Out-of-pocket expenditure on health, \$	64	67
Registered motor vehicles/1000 population, No.	2.9	6.7

Abbreviation: GDP, gross domestic product.

of trauma care development, and local socioeconomics. At least 1 district-level hospital in each region was selected by meeting the following criteria:

- In a populous area, near heavily trafficked roads likely to produce traffic injuries; *or*
- Identified by the respective regional health directorate as caring for a higher injury volume than others within the region; *or*
- Designated as a trauma hospital; *and*
- Outside 1 hour's transport to a regional or tertiary hospital.

In 2004, 10 hospitals were purposively sampled to represent regional and district-level hospitals in the southern regions (7 of the 10 regions).^{11,20} In 2014, all regional hospitals (except 1 that declined participation) and 30 district-level hospitals were sampled. To appositely compare hospitals from both studies, only the 32 district-level and regional hospitals representing the southern regions from the 2014 assessment were analyzed.

The 2004 study was approved by the Ghana Health Service. The 2014 study was approved by the Kwame Nkrumah University of Science and Technology Committee for Human Research and Publication Ethics and the University of Washington Institutional Review Board. In addition to ethical approval, approvals were obtained from the Ministry of Health and the Ghana Health Service. Informed consent was obtained from the leadership at each hospital prior to assessment. All data were anonymously recorded.

Data Collection

The World Health Organization *Guidelines for Essential Trauma Care* list 260 items of personnel and physical resources essential (ie, most cost-effective, universally applicable; eg, basic airway equipment) or desirable (ie, value-added, less cost-effective; eg, computed tomography) at different levels within a health care system. The assessments mutually examined 28 items from both groups; these items were used for the comparison. A technology item was defined as any electronic medical equipment (eg, mechanical ventilator, hemoglobin analyzer, radiography).

For both assessments, the following staff were asked to complete their respective part of the survey depending on context: surgeons, anesthesiologists, medical officers, professionals, technicians, and/or in-charge nurses from the casualty, theater, critical care, wards, laboratory, radiology, physiotherapy, procure-

ment, accounts, and engineering departments. Item availability was rated as the following: 0, absent but should be present; 1, inadequate, available to fewer than half of those who need it; 2, partially adequate, available to more than half but not to most who need it; or 3, adequate, present, readily available to almost everyone in need, and used when needed.

To further the usefulness of the 2014 reassessment, factors contributing to item ratings of 2 or lower were systematically assessed as the following: never been present; present but broken and awaiting repairs; present and staff able to use it, except at night or on the weekend; no staff member trained in using the available item; available but lacks reagents or supplies; necessary equipment or supplies out of stock or insufficient in number; available, but only after prepayment that prevents many from receiving the service or item; and/or other, with explanation.

Factors were not mutually exclusive, except for the category of never been present, which ruled out any other contributing factor. Direct inspection of items was performed to corroborate ratings and troubleshoot reason(s) for unavailability. Direct inspection included determining whether the item was present or absent, examining it for useful availability, and evaluating why it was not available at times if rated lower than 3.

Statistical Analysis

Data from 2004 have been published and were extracted for comparison.^{11,20} For the 2014 assessment, data were collected on paper forms and transcribed to Microsoft Excel (Microsoft Corp). Item availability ratings were described using Stata version 13 statistical software (StataCorp LP). Given that 8 of the 10 hospitals assessed in 2004 were reassessed in 2014, the Wilcoxon signed rank test was used to compare item availability ratings between the 2 assessments. Lastly, the number of hospitals that reported a specific factor contributing to each deficient item was calculated; each item rated lower than 3 at a specific hospital was defined as a hospital-item deficiency. Scores for total number of hospital-item deficiencies were derived for each of the major contributing factors to identify potential targets for interventions.

Results

District-Level Hospitals

In district-level hospitals, resuscitation and the requisite equipment and supplies were more dependably available in 2014 than in 2004. Most notable were basic and advanced airway equipment (mean rating increased from 1 in 2004 to 2 and 3, respectively in 2014), oxygen supply (rating increased from 1 to 3), pulse oximetry (rating increased from 0 to 3), and blood transfusion capabilities (rating increased from 1 to 2). The availability of chest tubes, a low-cost item, was lower in 2014 (mean rating of 0) than in 2004 (mean rating of 1) (Table 2).

Diagnostic services were not markedly different in 2014 compared with 2004. Determination of blood electrolytes and stationary radiography availability were better than at the initial assessment but had mean ratings less than 3 (Figure 1).

Table 2. Comparison of Availability of Trauma Care Services and Resources Necessary to Provide Them in 2004 and 2014 in Ghana

Item	Item Availability Rating, Mean ^a			
	District-Level Hospitals		Regional Hospitals	
	2004	2014	2004	2014
Hospitals assessed, No.	8	26	2	6
Airway				
Basic equipment ^b	1	2	2	2
Advanced equipment ^c	1	3	1	3
Breathing				
Oxygen supply	1	3	1	3
Chest tubes	1	0	1	0
Pulse oximetry	0	3	0	2
Bag valve mask	1	3	2	1
Mechanical ventilator	0	2	0	1
Circulation				
Urinary catheter	3	3	3	3
Blood transfusion capabilities	1	2	2	2
Electronic cardiac monitoring	0	0	0	1
Laboratory diagnostics				
Hemoglobin determination	3	3	3	3
Electrolyte determination	0	0	0	1
Arterial blood gas, lactate	0	0	0	0
Imaging diagnostics				
Stationary radiography	1	2	2	2
Portable radiography	1	0	2	0
FAST scan	1	0	1	0
Computed tomography	NA	NA	0	0
Angiography	NA	NA	0	0
General surgery				
Basic general surgery ^d	1	3	2	3
Major general surgery ^e	1	2	2	3
Skin grafting	1	0	2	1
Orthopedic surgery				
Skin or skeletal traction	1	0	2	3
External fixation	0	0	1	1
Internal fixation	0	0	1	1
Image intensification	0	0	0	2
Neurosurgery				
ICP monitoring	NA	NA	0	0
Basic neurosurgery ^f	1	0	1	0
Spinal fixation	NA	NA	0	0
Assessment mean ^g	0.8	1.3	1.1	1.4

Abbreviations: FAST, focused assessment with sonography for trauma; ICP, intracranial pressure; NA, not available.

^a Rating scheme was as follows: 0, absent; 1, inadequate, available to fewer than half of those who need it; 2, partially adequate, available to more than half but not to most who need it; and 3, adequate, present, readily available to almost everyone in need, and used when needed.

^b Oral and nasal airways or suction pump.

^c Endotracheal tubes or laryngoscope.

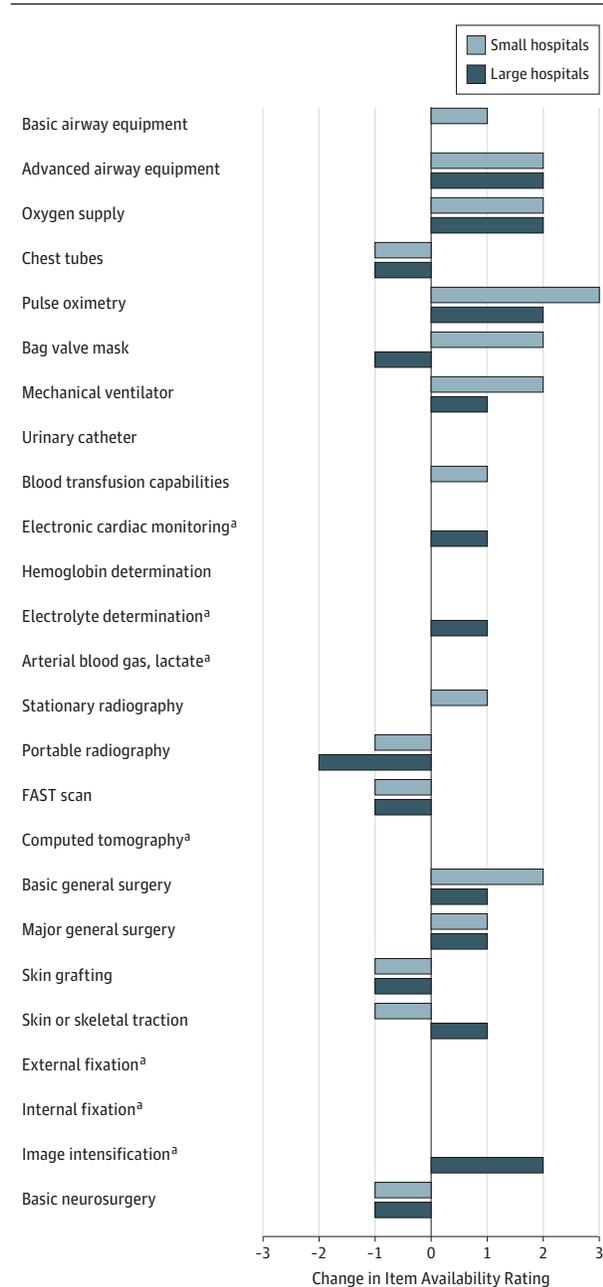
^d Wound debridement, 1% total body surface area burn excision, digital amputation, or surgical airway.

^e Neck exploration, exploratory laparotomy, or major amputation.

^f Burr hole or treatment of open depressed skull fracture.

^g Wilcoxon signed rank test was used to compare item availability ratings between the 2 assessments and within each hospital level. For district-level hospitals in 2014 vs 2004, $P = .002$; for regional hospitals in 2014 vs 2004, $P = .01$.

Figure 1. Changes in Availability of Trauma Care Services and the Resources Necessary to Provide Them Between 2004 and 2014 in Ghana



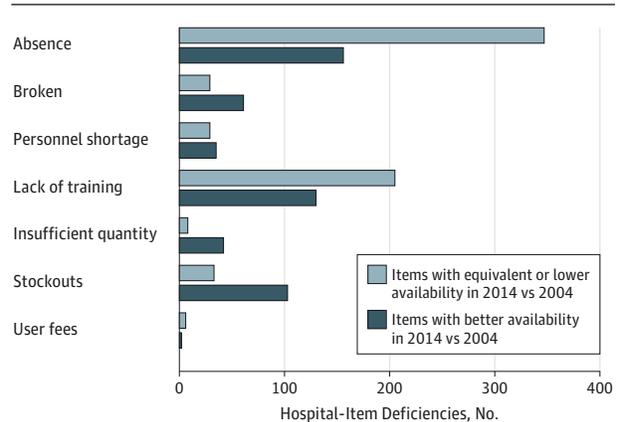
FAST indicates focused assessment with sonography for trauma.

^a Mean item availability rating was 0 in both assessments at district-level and/or regional hospitals.

General surgical capabilities were more consistently available (mean rating increased from 1 to 2); however, there were no improvements in the availability of skin grafting or basic orthopedic or neurosurgical operative capacity (ratings <2) (Table 2).

Overall, there was strong evidence for improvement in item availability at district-level hospitals in 2014 (mean rating of 1.3) compared with 2004 (mean rating of 0.8) ($P = .002$) (Table 2).

Figure 2. Factors Contributing to Hospital-Item Deficiencies for Services and Resources for Trauma Care in 2014 Compared With 2004 in Ghana



Hospital-item deficiency was defined as an item with a rating less than 3 at a specific hospital.

Regional Hospitals

Availability of resuscitation items at regional hospitals also markedly improved from 2004 and in a pattern similar to that of district-level hospitals. Although substantially improved from 2004, pulse oximetry, mechanical ventilation, and electronic cardiac monitoring remain deficient (mean ratings <3) (Table 2).

Mean ratings for laboratory and imaging diagnostics exactly mirrored district-level hospitals' ratings and were relatively unchanged from 2004, except for portable radiography availability, which was lower in 2014 (mean rating decreased from 2 to 0) (Figure 1).

Definitive care was more often available in regional hospitals than district hospitals and in 2014 compared with 2004. General surgical capabilities were dependably available (mean rating of 3), although skin grafting and internal fixation for fractures were rarely available (mean rating of 1). Importantly, intracranial pressure monitoring, neurosurgical operative capacity, and spinal fixation had no improvement or had a lower rating (mean rating of 0 in 2014) (Table 2).

As with district-level hospitals, regional hospitals had significantly improved item availability ratings in 2014 (mean rating of 1.4) compared with 2004 (mean rating of 1.1) ($P = .01$) (Table 2).

Factors Contributing to Deficiencies in 2014

Assessment of the factors contributing to specific resource deficiencies helps to identify which inputs (eg, training, financing mechanisms, stock management practices) likely contributed to improved availability and which factors remain to be confronted. The 3 most frequently reported causes of deficiencies were item absence (ie, never having been present at the facility; 503 hospital-item deficiencies), lack of training to use items that were present (335 hospital-item deficiencies), and stockout of consumables (137 hospital-item deficiencies) (Figure 2). If an item had been present at a facility before (ie, absence not a contributing factor), lack of training was the most commonly reported factor contributing to item deficiency.

Items that were deficient but with improved availability in 2014 compared with 2004 were more often broken, out of stock, or insufficient in quantity than items that did not have improved availability. Conversely, items that were deficient and with equivalent or lower availability in 2014 compared with 2004 were more often absent or not used because of a lack of training compared with items with improved availability.

Discussion

This study aimed to compare the availability of trauma care services and the resources necessary to provide them in Ghana between 2004 and 2014 and generate recommendations for potential interventions. While trauma care capacity was significantly better in 2014 at both district-level and regional hospitals, critical deficiencies remain (eg, training for basic procedures, technology items, and definitive care). Item absence and lack of training were the most common factors contributing to deficiency. Notably, items that did not have improved availability in 2014 compared with 2004 were more often not used owing to a lack of training compared with items that had improved availability. Without a systemwide approach to trauma care capacity improvements, reversal of the gains made and ongoing deficiencies will continue to result in preventable traumatic death and disability.

In 2003, Ghana passed the National Health Insurance Act to provide essential care to the majority of its citizens. Initially, the National Health Insurance Scheme resulted in improved access to care, better availability of consumables, and increased operating budgets.^{13,18,21} Notwithstanding early success, total timely reimbursement rates are now low owing to increasing reliance on a narrow tax base, a large informal sector, and significant health care use.^{13,18,22} During the 2014 assessment, lack of reimbursements was significantly hindering hospitals' ability to afford essential care items, in-service trainings, or repairs of broken technology.^{23,24} Concerted and sustained political effort in redressing the national insurance reimbursement scheme is needed to avoid ongoing, critical essential resource deficiencies for trauma care as well as other fundamental health care services.²⁵

Significant gains in service availability were identified for resources that required improvements primarily in training (eg, advanced airway management, basic and major surgery, basic fracture management). This may have been due in part to a homegrown trauma care continuing education course that ran for 15 years in Ghana. Despite established success, the Advanced Trauma Life Support course is often prohibitively expensive and inappropriate for the severe resource limitations commonly encountered in LMICs.^{26,27} Recognizing the need for a context-appropriate course, faculty at the Kwame Nkrumah University of Science and Technology developed a continuing education course specifically for rural district-level and regional hospitals in 1996.¹⁴ An annual 40-hour program that encompassed essential management of the injured patient for the general practitioner working with severe resource limitations was developed. In an assessment of the courses, pretest and posttest scores

documented good retention of the program's content.¹⁴ Follow-up assessments after 6 months and 2 years demonstrated that participants were significantly more comfortable with trauma management principles and procedures covered by the course. With help from the Ministry of Health, district health services shouldered course expenses (individual participant cost was \$135).¹⁴ Unfortunately, the course dissolved in 2011 owing to lack of funding and support. Given improvements documented by the training program and the recurrent or residual deficiencies in essential trauma care training, reinvigorating the trauma care continuing education course is a potentially important priority, particularly for improving definitive care capacity at district-level and regional hospitals. This also provides an instructive lesson for other LMICs by demonstrating the significant gains that can be made with regularly held, low-cost trauma care continuing education courses.

Blood transfusion capabilities were more often available than items requiring less advanced inputs (eg, basic airway supplies, chest tubes) in both assessments. This relatively complex service is afforded by dedicated vertical program funding for human immunodeficiency virus and maternal health. Although relatively successful for disease-specific interventions and providing some broader benefits, vertical programs may channel resources away from other pressing public health dilemmas, like injury control.^{28,29} However, dependable availability of these high-resource services demonstrates that it is possible to provide essential services when funding and political will align.^{25,30} Investment in trauma care not only will reduce the injury burden but also represents an opportunity for synergistically improving many aspects of health care systems (eg, prehospital and diagnostic services; emergency, essential surgical, and rehabilitative care).^{29,31}

Higher-cost technology not supported by vertical programs continues to be rarely available (eg, mechanical ventilation, blood electrolyte or arterial blood gas determination, radiography). Low availability of such equipment has been found to be the result of long breakage, software faults, and being maladapted to the environment of rural hospitals in LMICs.^{5,32} Although technology has the capacity to markedly improve health care service delivery in LMICs, it must come in parallel with the requisite development in infrastructure (eg, affordable and consistent electricity, network capabilities), biomedical engineering capacity, and technical support to avoid suboptimal use of costly equipment.³²⁻³⁴ Once items are made available and staff are trained to use them, ensuring that technology items remain functional becomes particularly important.

Basic neurosurgical capacity remains critically deficient at regional hospitals not only in Ghana but in many LMICs.^{31,35,36} Compliance with basic resource-appropriate standards of head injury care and capacity to accurately assess intracranial pressure, perform trepanation, and fix open depressed skull fractures can be lifesaving interventions, particularly when referral is not a viable option.^{35,37,38} Given that head injuries are among the leading causes of traumatic death and disability, improving access to essential neurosurgical and resuscitation capabilities is imperative to prevent a large number of secondary brain injuries and avoidable deaths.^{35,39}

This study had several limitations that should be considered when drawing conclusions from its results. First, the rating scheme used (0-3) was somewhat subjective. Ratings could be biased either higher (ie, if staff wanted to show that their hospital was better for job security or other reasons) or lower (ie, if staff wanted to advocate for more funding and/or resources). To strengthen response validity, respondents from multiple departments who interacted with the same item (eg, radiography: emergency department physicians, emergency department nurses, surgeons, nurse anesthetists, radiography technicians, biomedical engineers) were asked to rate its availability and responses were triangulated. Further, direct observation was performed to corroborate ratings. Nonetheless, the same scheme was used in both assessments and has been validated internationally.^{3,20,32} Second, the 2004 assessment did not include 3 northern regions or any tertiary hospital. The capacity of these facilities is an important component of the trauma care system in Ghana. Third, pediatric-specific trauma care items were more often deficient than adult-sized items in 2014.²⁴ The 2004 assessment did not specifically evaluate these items, disabling a potentially useful comparison. Last, we assessed trauma care services and resources. These constitute assessments of structure, which may or may not translate into improvements in the process or outcomes of care. However, improvements in trauma care structure have been shown to be positively correlated with improvements in process and patient outcome; therefore, clinically significant improvements could be expected.^{40,41} Despite these limitations, this study has the strengths of being an extensive multihospital comparison done using the same tool, performed in the same regions and hospitals, and managed by the same team. These results provide a reliable and particularly useful serial assessment of trauma care capacity. As such, they allow reasonable conclusions to be drawn about ways to improve trauma care capacity in Ghana and other LMICs.

Conclusions

Serial assessments of trauma care capacity in Ghana demonstrated significant improvements in both district-level and regional hospitals. For example, resuscitation equipment and supplies, diagnostic capacity, and surgical care services were more often available in 2014 than in 2004. However, serious deficiencies have recurred or remain, namely those related to continued item absence or insufficient training as well as stockouts and/or technology breakage. Specifically, for items that improved during the decade, remaining deficiencies were more often related to breakage and stockouts than items that did not improve, which were most often due to item absence or lack of training. These deficiencies must be overcome so that timely essential trauma care can be provided to the large and increasing number of injured persons in Ghana as well as other LMICs.⁴² By doing so, unnecessary death and disability might be prevented. To make strides in trauma care capacity development, maintaining funding and support for a continuing education course for district-level and regional hospital staff is needed. Next, dedicated funding for trauma care is required, particularly as the burden of injury from urbanization and motorization grows.¹⁹ This should begin with ensuring timely national health insurance reimbursements so that hospitals can reliably purchase essential trauma care items. Lastly, it should be reinforced to national and regional policy makers that funding for trauma care could be effectively leveraged to synergistically improve numerous facets of deficient health systems (eg, prehospital and diagnostic services; emergency, surgical, and rehabilitative care). Because surgical and trauma care capacity assessments are performed to plan interventions, serial assessment is a valuable tool for monitoring and evaluating health care development strategies in the setting of rapidly changing disease burden in LMICs.^{1,43}

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REFERENCES

1. Wong EG, Gupta S, Deckelbaum DL, Razek T, Kushner AL. Prioritizing injury care: a review of trauma capacity in low and middle-income countries. *J Surg Res*. 2015;193(1):217-222.
2. Mock C. Confronting the global burden of surgical disease. *World J Surg*. 2013;37(7):1457-1459.
3. Mock C, Lormand J, Goosen J, Joshipura M, Peden M. *Guidelines for Essential Trauma Care*. Geneva, Switzerland: World Health Organization; 2004.
4. Carlson LC, Lin JA, Ameh EA, et al. Moving from data collection to application: a systematic literature review of surgical capacity assessments and their applications. *World J Surg*. 2015;39(4):813-821.
5. Groen RS, Kamara TB, Dixon-Cole R, Kwon S, Kingham TP, Kushner AL. A tool and index to assess surgical capacity in low income countries: an initial implementation in Sierra Leone. *World J Surg*. 2012;36(8):1970-1977.
6. Henry JA, Orgoi S, Govind S, Price RR, Lundeg G, Kehr B. Strengthening surgical services at the soum (first-referral) hospital: the WHO Emergency

- and Essential Surgical Care (EESC) program in Mongolia. *World J Surg.* 2012;36(10):2359-2370.
7. Kushner AL, Kamara TB, Groen RS, Fadlu-Deen BD, Doah KS, Kingham TP. Improving access to surgery in a developing country: experience from a surgical collaboration in Sierra Leone. *J Surg Educ.* 2010;67(4):270-273.
 8. Son NT, Mock C. Improvements in trauma care capabilities in Vietnam through use of the WHO-IATSIIC Guidelines for Essential Trauma Care. *Int J Inj Contr Saf Promot.* 2006;13(2):125-127.
 9. Wong EG, Gupta S, Deckelbaum DL, et al. The International Assessment of Capacity for Trauma (INTACT): an index for trauma capacity in low-income countries. *J Surg Res.* 2014;190(2):522-527.
 10. Mock C, Quansah R, Kobusingye O, Goosen J. Trauma care in Africa: the way forward. *Afr J Trauma.* 2014;3(1):3-10. doi:10.4103/1597-1112.139448.
 11. Quansah RE, Mock C, Abantanga FA. Status of trauma care in Ghana. *Ghana Med J.* 2004;38(4):149-152. doi:10.4314/gmj.v38i4.36013.
 12. Martel J, Oteng R, Mould-Millman NK, et al. The development of sustainable emergency care in Ghana: physician, nursing and prehospital care training initiatives. *J Emerg Med.* 2014;47(4):462-468.
 13. McIntyre D, Garshong B, Mtei G, et al. Beyond fragmentation and towards universal coverage: insights from Ghana, South Africa and the United Republic of Tanzania. *Bull World Health Organ.* 2008;86(11):871-876.
 14. Mock CN, Quansah R, Addae-Mensah L, Donkor P. The development of continuing education for trauma care in an African nation. *Injury.* 2005;36(6):725-732.
 15. Agyei-Mensah S, de-Graft Aikins A. Epidemiological transition and the double burden of disease in Accra, Ghana. *J Urban Health.* 2010;87(5):879-897.
 16. Mock C, Juillard C, Joshipura M, Goosen J. *Strengthening Care for the Injured: Success Stories and Lessons Learned From Around the World.* Geneva, Switzerland: World Health Organization; 2010.
 17. World Bank. *GNI per Capita: Atlas Method.* Washington, DC: World Bank; 2014.
 18. Lagomarsino G, Garabrant A, Adyas A, Muga R, Otoo N. Moving towards universal health coverage: health insurance reforms in nine developing countries in Africa and Asia. *Lancet.* 2012;380(9845):933-943.
 19. Toroyan T, Ilaych K, Peden M. *Global Status Report on Road Safety 2013: Supporting a Decade of Action.* Geneva, Switzerland: World Health Organization; 2013.
 20. Mock C, Nguyen S, Quansah R, Arreola-Risa C, Viradia R, Joshipura M. Evaluation of trauma care capabilities in four countries using the WHO-IATSIIC Guidelines for Essential Trauma Care. *World J Surg.* 2006;30(6):946-956.
 21. Dalinjong PA, Laar AS. The National Health Insurance Scheme: perceptions and experiences of health care providers and clients in two districts of Ghana. *Health Econ Rev.* 2012;2(1):13.
 22. Sodzi-Tettey S, Aikins M, Awoonor-Williams JK, Agyepong IA. Challenges in provider payment under the Ghana National Health Insurance Scheme: a case study of claims management in two districts. *Ghana Med J.* 2012;46(4):189-199.
 23. Stewart BT, Quansah R, Gyedu A, Ankomah J, Donkor P, Mock C. Strategic assessment of trauma care capacity in Ghana. *World J Surg.* 2015;39(10):2428-2440.
 24. Ankomah J, Stewart BT, Oppong-Nketia V, et al. Strategic assessment of the availability of pediatric trauma care equipment, technology and supplies in Ghana [published online March 26, 2015]. *J Pediatr Surg.* doi:10.1016/j.jpedsurg.2015.03.047.
 25. Quansah R. Essential trauma care in Ghana: adaptation and implementation on the political tough road. *World J Surg.* 2006;30(6):934-939.
 26. American College of Surgeons Committee on Trauma. *Advanced Trauma Life Support Program for Doctors: Instructor Manual.* Chicago, IL: American College of Surgeons; 1997.
 27. Williams MJ, Lockey AS, Culshaw MC. Improved trauma management with Advanced Trauma Life Support (ATLS) training. *J Accid Emerg Med.* 1997;14(2):81-83.
 28. Ooms G, Van Damme W, Baker BK, Zeitz P, Schrecker T. The "diagonal" approach to Global Fund financing: a cure for the broader malaise of health systems? *Global Health.* 2008;4:6.
 29. Patel PB, Hoyler M, Maine R, Hughes CD, Hagander L, Meara JG. An opportunity for diagonal development in global surgery: cleft lip and palate care in resource-limited settings. *Plast Surg Int.* 2012;2012:892437.
 30. Mills EJ, Ford N. Political lessons from the global HIV/AIDS response to inform a rapid noncommunicable disease response. *AIDS.* 2012;26(9):1171-1173.
 31. LeBrun DG, Chackungal S, Chao TE, et al. Prioritizing essential surgery and safe anesthesia for the Post-2015 Development Agenda: operative capacities of 78 district hospitals in 7 low- and middle-income countries. *Surgery.* 2014;155(3):365-373.
 32. Shah MT, Joshipura M, Singleton J, et al. Assessment of the availability of technology for trauma care in India. *World J Surg.* 2015;39(2):363-372.
 33. Tomasi E, Facchini LA, Maia MF. Health information technology in primary health care in developing countries: a literature review. *Bull World Health Organ.* 2004;82(11):867-874.
 34. Williams F, Boren SA. The role of the electronic medical record (EMR) in care delivery development in developing countries: a systematic review. *Inform Prim Care.* 2008;16(2):139-145.
 35. Alexander T, Fuller G, Hargovan P, Clarke DL, Muckart DJ, Thomson SR. An audit of the quality of care of traumatic brain injury at a busy regional hospital in South Africa. *S Afr J Surg.* 2009;47(4):120-122, 124-126.
 36. Nordberg E, Mwobobia I, Muniu E. Major and minor surgery output at district level in Kenya: review and issues in need of further research. *Afr J Health Sci.* 2002;9(1-2):17-25.
 37. Ratanalert S, Kornsilp T, Chintragoolpradub N, Kongchoochouy S. The impacts and outcomes of implementing head injury guidelines: clinical experience in Thailand. *Emerg Med J.* 2007;24(1):25-30.
 38. Ramesh A, Fezeu F, Fidele B, et al. Challenges and solutions for traumatic brain injury management in a resource-limited environment: example of a public referral hospital in Rwanda. *Cureus.* 2014;6(5):e179. doi:10.7759/cureus.179.
 39. Casey ER, Muro F, Thielman NM, et al. Analysis of traumatic injuries presenting to a referral hospital emergency department in Moshi, Tanzania. *Int J Emerg Med.* 2012;5(1):28.
 40. Moore L, Lavoie A, Sirois MJ, et al. Evaluating trauma center structural performance: the experience of a Canadian provincial trauma system. *J Emerg Trauma Shock.* 2013;6(1):3-10.
 41. Moore L, Lavoie A, Bourgeois G, Lapointe J. Donabedian's structure-process-outcome quality of care model: validation in an integrated trauma system. *J Trauma Acute Care Surg.* 2015;78(6):1168-1175.
 42. Institute for Health Metrics and Evaluation. *Data Visualizations: Global Burden of Disease Cause Patterns.* Seattle, WA: Institute for Health Metrics & Evaluation; 2013.
 43. Stewart B, Khanduri P, McCord C, et al. Global disease burden of conditions requiring emergency surgery. *Br J Surg.* 2014;101(1):e9-e22.

NEXT STEPS

This study not only demonstrated changes in trauma care capacity over time, but also highlighted the utility of serial assessments in benchmarking capacity development. Before committing resources to serial assessments, more is required to determine the validity of these metrics as a proxy for important outcomes (e.g., volume, quality, safety, timeliness of surgical care).

Although capacity assessments, like the one described in Chapter 2, have been used as proxies for surgical output, the linkage between the availability of surgical resources and surgical volume has not been well established. Given that capacity assessments are being used with increasing frequency to benchmark global surgery, it is important that we understand what is being measured and its relation to the goal of essential surgery capacity building – improving access to safe, timely, and affordable surgical care when needed. Therefore, we set out to explore the relationship between essential trauma and surgical capacity with output, measured as both volume and rate of operations per 100,000 persons.

CHAPTER 4 – EXPLORING THE RELATIONSHIP BETWEEN SURGICAL CAPACITY AND OUTPUT IN GHANA: CURRENT CAPACITY ASSESSMENTS MAY NOT TELL THE WHOLE STORY

OBJECTIVES

Objective 4. Compare the results of the capacity assessment at each hospital with results from surgical logbook data to examine the validity of currently proposed metrics for surgical capacity (e.g. surgical case rate per 100,000 population) and the relationship between capacity and output.

WORK IN CONTEXT

Capacity assessments are used as surrogates for surgical output. In keeping with the Donebedian model of quality improvement described in Chapter 1, it is presumed that improvements in structure (i.e., human and physical resources) would be followed by similar improvements in processes and outcomes (e.g., surgical volume or output). However, this relationship has not been well established. Anecdotally, there did not seem to be a strong association between the availability of trauma and surgical resources and surgical output for injury or other conditions.

Given that capacity assessments are being used with increasing frequency to benchmark global surgery, it is important that we understand what is being measured and its relation to the goal of essential surgery capacity building – improving access to safe, timely, and affordable surgical care when needed. Therefore, we aimed to explore the relationship between essential trauma and surgical capacity with output, measured as both volume and rate of operations per 100,000 persons.

CANDIDATE INVOLVEMENT

The candidate designed the study, sought relevant approvals with the assistance of mentoring Professors, collected data and performed key informant interviews at all hospitals, transcribed and managed the data, analyzed the data, and drafted the manuscript. The candidate supervised the collection and transcription of surgical logbooks, which was performed by trained research assistants.

CO-AUTHOR INVOLVEMENT

RQ, PD, JV, and CM reviewed the design of the study, assisted with introductions to get approvals for the study, and reviewed the manuscript. AG, CG, GB and JA assisted with data collection, reviewed the results and manuscript. All authors approved the final manuscript draft prior to publication.

ETHICS

Approvals from Kwame Nkrumah University of Science and Technology, the Ghana Health Service, and the University of Washington can be found in Appendix 3.1 – 3.4. Stellenbosch University reviewed of all projects herein and found the ethics approvals appropriate. It was determined that the projects were exempt from further review. The letter from Stellenbosch University can be found in Appendix 3.5.

Exploring the Relationship Between Surgical Capacity and Output in Ghana: Current Capacity Assessments May Not Tell the Whole Story

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Abstract

Objective Capacity assessments serve as surrogates for surgical output in low- and middle-income countries where detailed registers do not exist. The relationship between surgical capacity and output was evaluated in Ghana to determine whether a more critical interpretation of capacity assessment data is needed on which to base health systems strengthening initiatives.

Methods A standardized surgical capacity assessment was performed at 37 hospitals nationwide using WHO guidelines; availability of 25 essential resources and capabilities was used to create a composite capacity score that ranged from 0 (no availability of essential resources) to 75 (constant availability) for each hospital. Data regarding the number of essential operations performed over 1 year, surgical specialties available, hospital beds, and functional operating rooms were also collected. The relationship between capacity and output was explored.

Results The median surgical capacity score was 37 [interquartile range (IQR) 29–48; range 20–56]. The median number of essential operations per year was 1480 (IQR 736–1932) at first-level hospitals; 1545 operations (IQR 984–2452) at referral hospitals; and 11,757 operations (IQR 3769–21,256) at tertiary hospitals. Surgical capacity and output were not correlated ($p > 0.05$).

Conclusions Contrary to current understanding, surgical capacity assessments may not accurately reflect surgical output. To improve the validity of surgical capacity assessments and facilitate maximal use of available resources, other factors that influence output should also be considered, including demand-side factors; supply-side factors and process elements; and health administration and management factors.

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Introduction

Healthcare capacity assessments have been used to document baseline availability of resources and capabilities, benchmark capacity improvements over time or after interventions, and plan targeted development activities [1, 2]. Assessments of the surgical capacities of low- and middle-income countries (LMICs) across the globe have repeatedly demonstrated critical resource deficiencies that are assumed to preclude the delivery of safe surgical care; [1] in addition to the functions above, results from these assessments have laid the groundwork for advocacy aimed at increasing and focusing attention, research, and funding toward the gross health inequity that results from insufficient population access to surgical care [1, 3].

Partly as result of this advocacy, the World Health Assembly (WHA) ratified resolution 68.15: ‘Strengthening emergency and essential surgical care and anesthesia as a component of universal health coverage.’ [4] In this resolution, the WHA recognized the need for ‘relevant, meaningful, and reliable measures of safe emergency and essential surgery and anesthesia’ to guide health system strengthening efforts and foster political and public support. Currently, few LMICs have standardized system-wide surgical registries or mechanisms to monitor the burden of conditions that require surgical care; both of which exist for other services and conditions (e.g., TB, HIV, maternal and child health, vaccine-preventable disease) [5]. Therefore, many LMICs continue to rely on assessments of surgical capacity as surrogates for output (or output relative to the population) to determine the potential ability for facilities to provide safe surgical care and potentially meet the needs of their populations [2, 6].

One of the principal surgical capacity assessment tools is the World Health Organization (WHO) Tool for Situational Analysis to Assess Emergency and Essential Surgical Care (TSAEEESC), which, along with complementary WHO guidelines for emergency, surgical and trauma care, has been the model for a number of other locally adapted assessment tools [1, 7–9]. Given the weight that the global surgery community, governments, and health system planners place on these assessments, it is important that they accurately reflect surgical output so that useful decision-making can occur. The tool has demonstrated relatively high inter-rater agreement and reliability over time, namely from studies performed in Ghana [2, 10]. However, there has not been a report that documents the validity of this or other capacity assessment tools; further, no report has examined the relationship between surgical capacity and output (i.e., number of operations performed per year) [10, 11].

To address this gap, we aimed to explore the relationship between surgical capacity and output at hospitals in Ghana. By doing so, we might improve our ability to interpret capacity assessments; more accurate interpretation of assessments and understanding of the relationship between surgical capacity and output will allow better targeting of interventions to improve surgical care delivery.

Methods

Setting

Ghana is a lower-middle-income country in West Africa with a population of nearly 26 million people [12]. Ghana has 10 regions divided into 216 districts. The healthcare system has four levels of care: primary health centers (PHC) and 155 district (first-level), nine regional (referral), and four tertiary hospitals. Most districts have several PHCs, and about 60% of districts have a government or mission hospital that serves as a first-level hospital [13]. PHCs provide basic public health and primary care services; though an important initial site of contact for some surgical patients, these facilities were not assessed as this study focused on hospital-based surgical care. First-level hospitals are staffed by medical officers and nurse anesthetists; these facilities usually offer at least some surgical services and have between 50 and 100 beds [14]. Patients requiring more complex care are transferred, as possible, to one of the referral or tertiary hospitals [15]. In addition to medical officers and nurse anesthetists, referral hospitals are typically staffed by specialist surgical providers (e.g., general, obstetric, and orthopedic surgeons) and contain between 100 and 500 beds. Tertiary hospitals typically offer a broad range of surgical services and have between 500 and 2000 beds.

Capacity assessment

In 2014–15, we performed a nationwide surgical and trauma care capacity assessment to inform targeted health system strengthening activities [14, 16–18]. We used a survey instrument adapted from WHO guidelines (e.g., TSAEEESC, Guidelines for Essential Trauma Care, Generic Essential Emergency Equipment List) [7–9] and The World Bank Disease Control Priorities Project, 3rd Edition (DCP³); [19] these guidelines list resources and capabilities considered to be *essential* or *desirable* at different levels within a healthcare system. ‘Essential’ resources and capabilities are considered most cost-effective, universally applicable, and have the highest potential population impact. The assessment in Ghana examined the entirety of resources and capabilities listed in the guidelines above;

however, this study focused on 25 essential surgical resources or capabilities, which served as proxies for surgical capacity more broadly (Table 1). We did not collect data on essential dental, ophthalmologic, oral-maxillofacial, or advanced pediatric surgical capacity; thus, operations typically performed under the auspices of these specialties were not included in the analysis.

Sample strategy

First-level hospitals were purposively sampled to represent those most likely to care for patients with surgical conditions, the diversity of surgical care development, and the variation in geography and local socioeconomics [20]. At least two first-level hospitals in each region (based on region population size) were selected by being: in a populous area, *or* identified by the respective Ministry of Health Regional Health Directorate as caring for a higher surgical volume than others within the region, *or*

designated as a surgical or trauma hospital by the Ministry of Health; *and* outside of an hour's transport to a referral or tertiary hospital. Using these criteria, we sampled 26 first-level hospitals. Referral and tertiary hospitals were exhaustively sampled, save one each that declined participation.

At each hospital, one or more of the following (depending on local context) key informants were asked to complete their respective section of the capacity assessment tool by study team members to triangulate responses: surgeons, anesthetists, medical officers, professionals, technicians, and/or in-charge nurses from the casualty, theater, critical care, wards, laboratory, radiology, physiotherapy, procurement, accounts, and engineering departments. In keeping with other published assessments, resource availability was rated as: [21–24].

0—Absent but should be present;

Table 1 Essential surgical resources and capabilities assessed at first-level, referral, and tertiary hospitals in Ghana

Resource or capability	Example elements
Personal protective and sterile attire equipment	Mask, gloves, impervious gowns, boots, hats, eye shields, of various sizes
Basic airway management	Nasal and oral airways, bag-valve-mask, Magill forceps, stethoscope
Suction device	Electric, foot-pump or otherwise with tubing and appropriate tip
Advanced management	Laryngoscope, lighted blades and endotracheal tubes of various sizes
Spine immobilization	Cervical collars or safely improvised device
Oxygen supply	Oxygen concentrator, tank or wall source; nasal cannulas and masks of various sizes
Tube thoracostomy	Various sizes, water seal device and instruments to insert
Pulse oximetry	Machine and probe
Mechanical ventilator	Machine and tubing
Blood transfusion	Safe blood collection, testing, storage and administration system
Hemoglobin	Manual or automated counting
X-ray	Stationary or portable X-ray
Ultrasound	Machine and probe(s)
Anesthesia machine	Machine and anesthetic gas
Minor surgical	Suture of laceration, incision and drainage, circumcision, herniorrhaphy, hydrocelectomy
Major surgical	Laparotomy for acute abdomen or injury, cholecystectomy, colostomy
Obstetric and gynecologic	Normal, instrumented and Cesarean birth; laparotomy for ectopic pregnancy, dilation, and curettage, tubal ligation, hysterectomy, inspection and/or cryotherapy for precancerous lesions
Urologic	Relief of urinary obstruction (urethral or suprapubic catheterization), vasectomy
Closed reduction	Closed reduction, splinting and casting
Skin or skeletal traction	Skin or skeletal traction, including chord and weights
Minor orthopedic	Drainage of septic arthritis, toileting of open fracture, debridement for osteomyelitis, non-operative club foot management
Major orthopedic	Fasciotomy, amputation
Vascular	Control, shunting and repair of major vascular injury
Burn and plastic	Skin grafting, escharotomy
Minor neurosurgical	Burr hole placement; management of open, depressed skull fracture, shunt for hydrocephalus

- 1—Inadequate, available to less than half of those who need it;
- 2—Partially adequate, available to more than half, but not to most who need it; or
- 3—Adequate, present and readily available to almost everyone in need and used when needed.

Direct inspection of each of the resources was performed to corroborate ratings and ensure data validity.

Composite capacity score, surgical specialty availability, and hospital infrastructure

Ratings for the 25 essential surgical care resources and capabilities were summed to obtain a composite capacity score that ranged from 0 (no essential resource availability) to 75 (full and constant essential resource availability). At each facility, we also collected data on the availability of surgical specialties (e.g., in-hospital or on-call availability of specialty-trained surgeons with certification from the West African College of Surgeons in the fields of general surgery, obstetrics and gynecology, orthopedic surgery, urology, neurosurgery, plastic surgery, head and neck surgery, maxillofacial surgery, ophthalmology, pediatric, cardiovascular or thoracic surgery). Data on the surgical output of non-surgeons were not collected, as there is no formal general or special surgical training or certification for non-surgeons in Ghana analogous to surgical task-sharing programs in other countries [25–28]. First-level hospitals in Ghana consistently have between 50 and 100 beds and 1–3 operating rooms or procedure areas that are intermittently functional [14, 29]; however, referral and tertiary hospitals vary in bed capacity and the number of operating rooms. Therefore, we collected data on the number of hospital beds and number of functional operating rooms and/or procedure areas at referral and tertiary hospitals.

Surgical output

At each of the 37 hospitals, de-identified surgical logbook data from June 1, 2014, to May 31, 2015, from each operating room and/or procedure area were transcribed into Excel (Microsoft Corp., USA) by two study team members; a third member resolved data inconsistencies using the original logbook. The team members who collected the capacity data were different from those who collected the output data; therefore, the team collecting the capacity data was blinded to the hospitals' outputs, and the team collecting the output data was blinded to the hospitals' capacity.

Our de facto definition of an 'operation' was: A procedure performed in an operating room or procedure area

regardless of anesthesia type or type of provider performing the procedure. If more than one procedure was performed during a single 'operation,' only the primary procedure was counted. Operations were categorized as either 'essential' (i.e., most cost-effective, universally applicable, highest potential population impact) or 'advanced' (i.e., more expensive and/or complex, less potential population impact) using the guidelines from The World Bank DCP³ [3].

Data analysis

The composite surgical capacity score was described and found to be normally distributed (skewness 0.39, kurtosis 2.99, Shapiro–Wilk $p = 0.62$), as well as highly collinear with both the number of hospital beds and number of functional operation rooms and/or procedure areas (condition number 14.3 to 8.9 with the latter covariates excluded). Since surgical output was measured as counts, we sought to explore the relationship between surgical capacity and output using a Poisson model. However, the mean of the surgical output covariate was greater than its variance, which suggested significant over-dispersion; given over-dispersion and the observation that all of the sampled hospitals performed at least one operation, we explored the relationship between the surgical capacity score and surgical output using a zero-truncated negative binomial regression model [30, 31]. Bootstrap resampling was used to calculate standard errors and 95% uncertainty intervals (UIs). The initial model included a priori-defined terms for the capacity score and number of surgical specialties available, hospital beds, and functional operating rooms and/or procedure areas, which have been shown to correlate with surgical output [32]. After, we performed backward stepwise regression (covariate removed from the model if $p \geq 0.10$) given the relatively small number of covariates to determine whether omitting one or more of the additional explanatory covariates (i.e., covariates other than the composite capacity score) improved model fit. Using Akaike's information criterion, model fit was marginally better after omitting number of hospital beds and number of functional operating rooms and/or procedure areas from the model [33, 34]. Next, we compared the above models with and without omitting hospitals that had either a capacity score or output outlier with significant leverage and/or influence on the model; model fit was again improved with the omission of seven outlier hospitals. The final model was:

Number of operations performed per year_{*i*}
 $= e^{\beta_0} \times e^{\beta_1}$ (composite surgical capacity score_{*i*})
 $\times e^{\beta_2}$ (number of surgical specialties available_{*i*})

Ethical considerations

This study was approved by the ethical committees of the Kwame Nkrumah University of Science and Technology and the University of Washington. All participants gave informed consent, and all data were anonymously recorded.

Results

Hospital characteristics and essential surgical care capacity

Surgical capacity was assessed and surgical output data were collected from 37 hospitals: 26 first-level hospitals (70%), 8 referral hospitals (22%), and 3 tertiary hospitals (8%) (Table 2). All hospitals had medical officers who were able to perform some degree of surgical care; 5 hospitals had one surgical specialty available (14%); 11 hospitals had two specialties available (30%); 5 hospitals had three or four specialties available (14%); and 3 hospitals had five or more specialties available (8%) (Table 3).

Generally, there was greater availability of resources and capabilities at higher levels of care (i.e., first-level resource and capability availability < referral < tertiary hospitals) (Table 2). This was particularly the case for availability of blood transfusion, non-general surgical capabilities (e.g., orthopedic surgery, neurosurgery), and anesthesia machines. Several resources and capabilities were often available at all hospital levels, such as personal protective equipment, airway management, oxygen supply, and hemoglobin testing. However, several essential surgical care capabilities were not readily available even at tertiary centers (e.g., essential procedure capabilities for urology, major orthopedic, vascular, burn and plastic, and minor neurosurgical care).

The median composite surgical capacity score was 37 [interquartile range (IQR) 29–48; range 16–69] (Table 3); the score increased (i.e., greater capacity) and had a narrower distribution (i.e., more similar capacity) with increasing level of care: median surgical capacity score at first-level hospitals—34.5 (IQR 29–40; range 16–62); referral hospitals—38.5 (IQR 36–49; 16–56); tertiary hospitals—60.0 (IQR 53–69; 53–69).

Surgical output

There was marked variation in the surgical output across and within each hospital level. The median number of

Table 2 Essential surgical resources and capabilities available at first-level, referral, and tertiary hospitals in Ghana

	Median item availability rating (range)		
	First-level (26)	Referral (8)	Tertiary (3)
<i>Airway and PPE</i>			
Personal protective equipment	2 (1–3)	3 (2–3)	3 (2–3)
Basic management	2 (0–3)	2 (0–3)	2 (2–3)
Suction device	2 (0–3)	2 (0–3)	2 (2–3)
Advanced management	3 (0–3)	3 (0–3)	3 3
Spine immobilization	0 (0–3)	0 (0–1)	1 (0–3)
<i>Breathing</i>			
Oxygen supply	3 (1–3)	3 (2–3)	3 (2–3)
Tube thoracostomy	0 (0–3)	0 (0–2)	3 (2–3)
Pulse oximetry	3 (0–3)	2 (2–3)	3 (2–3)
Mechanical ventilator	2 (0–2)	1 (0–3)	3 (1–3)
<i>Circulation and laboratory</i>			
Blood transfusion	2 (1–3)	2 (1–3)	2 (2–3)
Hemoglobin	3 (1–3)	3 (2–3)	3 3
<i>Imaging</i>			
X-ray	2 (0–3)	2 (0–3)	2 (2–3)
Ultrasound	0 (0–3)	0 (0–2)	3 (0–3)
<i>Surgical capabilities</i>			
Anesthesia machine	2 (0–2)	2 (1–3)	3 (2–3)
Minor general surgical	3 (0–3)	3 (0–3)	3 (2–3)
Major general surgical	1 (0–3)	3 (0–3)	3 (2–3)
Obstetric and gynecologic	3 (0–3)	3 (1–3)	3 3
Urologic	1 (0–3)	2 (1–3)	3 (1–3)
Closed reduction	2 (0–3)	3 (0–3)	3 3
Skin or skeletal traction	0 (0–3)	2 (0–3)	3 (2–3)
Minor orthopedic	0 (0–3)	0 (0–3)	3 3
Major orthopedic	0 (0–3)	0 (0–1)	2 (1–3)
Vascular	0 (0–2)	0 (0–2)	1 (0–3)
Burn and plastic	0 (0–3)	0 (0–2)	2 (1–3)
Minor neurosurgical	0 (0–1)	0 0	1 (0–3)

PPE personal protective equipment; rating scheme: 0—absent; 1— inadequate, available to less than half of those who need it; 2— partially adequate, available to more than half, but not to most who need it; 3—adequate, present and readily available to almost everyone in need and used when needed

essential operations performed annually at first-level hospitals was 1581 operations (IQR 736–2167) compared to 1676 operations (IQR 1019–2643) at referral hospitals and 12,509 operations (IQR 3773–22,260) at tertiary hospitals. Further, higher hospital levels performed a greater proportion of operations not considered ‘essential’ by The World Bank; these operations represented 25% of operations performed at first-level hospitals, 36% at referral hospitals, and 43% at tertiary hospitals.

Table 3 Capacity, surgical specialty availability, and surgical output from first-level, referral, and tertiary hospitals in Ghana

	Capacity score	Surgical specialty availability ^a	Number of essential operations	Number of advanced operations	Total number of operations
First-level (median)	34.5	1	1480	460	2050
Hospital 1	16	0	708	21	728
Hospital 2	18	0	736	80	816
Hospital 3	20	2	1726	439	2165
Hospital 4	22	0	1188	294	1483
Hospital 5	23	1	1222	654	1875
Hospital 6	25	0	1100	933	2033
Hospital 7	29	0	3661	483	4144
Hospital 8	29	2	1932	455	2387
Hospital 9	29	0	1873	351	2224
Hospital 10	32	0	426	39	465
Hospital 11	33	0	390	483	873
Hospital 12	33	2	2260	568	2829
Hospital 13	34	1	1589	178	1767
Hospital 14	35	2	2154	493	2648
Hospital 15	37	0	803	23	827
Hospital 16	38	0	1925	142	2067
Hospital 17	38	0	1578	1413	2991
Hospital 18	40	2	1240	54	1294
Hospital 19	40	2	88	34	121
Hospital 20	40	0	320	67	387
Hospital 21	43	1	3172	561	3733
Hospital 22	48	2	3712	940	4653
Hospital 23	49	1	8220	2441	10,661
Hospital 24	50	3	1852	3309	5161
Hospital 25	51	2	150	465	615
Hospital 26	62	2	1382	883	2266
Referral (median)	38.5	3	1545	658	2497
Hospital 1	16	1	411	40	451
Hospital 2	36	0	1066	259	1325
Hospital 3	36	2	3750	730	4480
Hospital 4	37	2	1408	601	2009
Hospital 5	40	3	2361	715	3076
Hospital 6	47	4	1681	1303	2984
Hospital 7	51	4	2542	773	3316
Hospital 8	56	4	902	586	1487
Tertiary (median)	60	7	11,757	3839	15,596
Hospital 1	53	6	3769	1606	5375
Hospital 2	60	10	21,256	17,182	38,438
Hospital 3	69	7	11,757	3839	15,596
All hospitals (median)	37	2	1589	493	2165

Capacity score—a composite score of 25 essential surgical care resources as outlined by the World Health Organization and The World Bank, the score ranges from 0 (no essential resource availability) to 75 (full and constant essential resource availability)

^aSurgical specialty availability—in-hospital or on-call availability of general surgery-, obstetrics and gynecology-, orthopedics-, and/or urology-trained surgeon(s); number of operations performed from May 31st to June 1st 2014–2015, respectively; operations were categorized as either ‘essential’ (i.e., most cost-effective, universally applicable, highest potential population impact) or ‘advanced’ (i.e., more expensive and/or complex, less potential population impact) using the guidelines from The World Bank Disease Control Priorities Project 3rd Edition

Table 4 Relationship between surgical capacity and surgical output at hospitals in Ghana

	Coefficient	Lower UI	Upper UI	<i>p</i> value
Essential surgical output				
Composite surgical capacity score	0.002	− 0.029	0.032	0.90
Number of surgical specialties available	0.150	− 0.002	0.302	0.05
Advanced surgical output				
Composite surgical capacity score	0.009	− 0.025	0.043	0.60
Number of surgical specialties available	0.330	0.088	0.572	0.01
Total surgical output				
Composite surgical capacity score	0.005	− 0.014	0.024	0.59
Number of surgical specialties available	0.190	0.085	0.295	0.01

Surgical output defined as number of operations performed per year; operations were categorized as either ‘essential’ (i.e., most cost-effective, universally applicable, highest potential population impact) or ‘advanced’ (i.e., more expensive and/or complex, less potential population impact) using the guidelines from The World Bank Disease Control Priorities Project 3rd Edition; composite surgical capacity score—a composite score of 25 essential surgical care resources as outlined by the World Health Organization and The World Bank, the score ranges from 0 (no essential resource availability) to 75 (full and constant essential resource availability); surgical specialty availability—in-hospital or on-call availability of general surgery-, obstetrics and gynecology-, orthopedics-, and/or urology-trained surgeon(s)

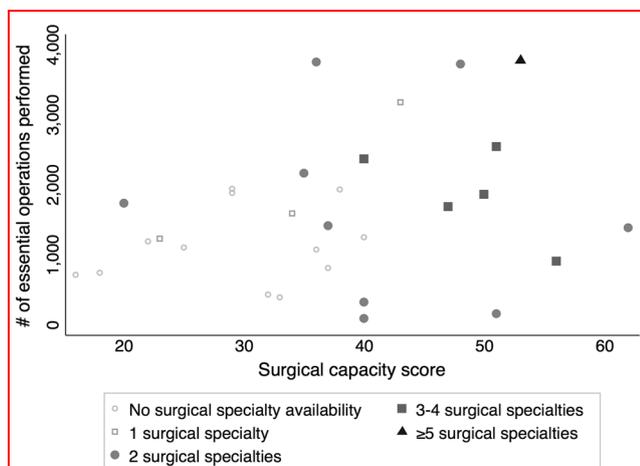


Fig. 1 Relationship between surgical care capacity and essential surgical output at hospitals in Ghana. Capacity score—a composite score of 25 essential surgical care resources as outlined by the World Health Organization and The World Bank, the score ranges from 0 (no essential resource availability) to 75 (full and constant essential resource availability); surgical specialty coverage—in-hospital or on-call availability of general surgery-, obstetrics and gynecology-, orthopedics-, and/or urology-trained surgeon(s); operations performed per year—number of essential operations as defined by The World Bank Disease Control Priorities Project 3rd Edition performed from May 31 to June 1, 2014–2015, respectively; seven hospitals that had either a capacity score or output outlier with significant leverage and/or influence on the model were excluded

Relationship between capacity and output

The model did not demonstrate evidence for a predictive relationship between surgical capacity and essential surgical output (i.e., number of essential operations performed annually; $p = 0.90$) (Table 4; Fig. 1), advanced surgical output (i.e., number of advanced operations performed

annually; $p = 0.60$), or total surgical output ($p = 0.59$). On the contrary, there was evidence for a relationship between surgical specialty availability and essential, advanced, and total surgical output ($p = 0.05$, $p = 0.01$ and $p = 0.01$, respectively).

Discussion

This study aimed to explore the relationship between surgical capacity and output at hospitals in Ghana to improve our understanding and interpretation of capacity assessment results. Despite the use of a robust and widely accepted method for assessing surgical capacity at a large number of hospitals countrywide, we did not find a strong relationship between capacity and output. This finding provokes three important considerations: (1) existing surgical capacity assessment tools that rely predominantly on measurement of availability of infrastructure, physical and human resources, and surgical capabilities may not accurately reflect surgical output; (2) the availability of specialty-trained surgeons improves surgical output; and (3) additional factors that influence output may need to be incorporated into future assessments to improve their accuracy, including other demand-side factors (e.g., barriers to care), supply-side factors (e.g., policies, protocols, incentivization structures, compliance), and health administration and management factors (e.g., an enabling work environment, emotional infrastructure, financing schemes). By considering these additional factors potentially related to output, we may be able to improve the validity of surgical capacity assessments to more accurately reflect the ability to provide safe, effective, and efficient care, and

facilitate the maximal use of existing and potential capacity through targeted health systems strengthening initiatives.

Demand-side factors that may reduce surgical output regardless of capacity include population awareness of surgical needs, access to care, and ease of healthcare navigation. A survey of patients with neglected surgical conditions from Ghana demonstrated that a complex amalgamation of cultural, financial, and structural barriers variably prevent many people from knowing when to seek care, seeking care, and receiving care beyond a simple lack of capable hospitals within a reasonable distance to their home [35]. Further, nearly 30% of Ghanaians are unable to reach a hospital capable of providing essential surgical care within 2 h, which results in variable presentations to care [18]. Further still, a study of population-level financial risk in Ghana demonstrated an inverse relationship between total household income and distance to surgical care, which is correlated with risk of both impoverishing and catastrophic health expenditure when care is required [36]. Surgical capacity is useless and becomes untethered to output when patients do not seek or are unable to access the resources available; therefore, future capacity assessments should consider including concurrent evaluation of the barriers to the care the patients face to facilitate the interpretation of surgical output across hospitals within a healthcare system and design of interventions to maximize resource allocation.

Supply-side factors other than essential resource availability that may reduce surgical output include the availability of additional: (1) structure elements (e.g., policies, protocols, incentivization structures); (2) process elements (e.g., service delivery, compliance with guidelines); and (3) health administration and management elements (e.g., enabling work environment, emotional infrastructure, financing schemes). Of course, a baseline level of context-appropriate physical and human resource availability is required to provide essential surgical care; however, once these resources are established, other non-material resources may become particularly important for maximizing surgical safety, effectiveness, and efficiency. For example, addition of structural and process improvements to mature trauma systems (i.e., well-resourced systems) produces safer and more effective trauma surgical care [37]. Therefore, as physical and human resources become more available, the availability of certain 'essential' non-material resources and capabilities (e.g., policies, protocols, compliance with guidelines) should be agreed upon by stakeholders and measured in future capacity assessments [38]. Additionally, this study demonstrates the potential positive impact of specialty-trained surgeons on surgical output; efforts to grow this segment of the workforce should exist in parallel to other initiatives, such as task-sharing [3, 27, 28, 39].

Current assessments do not consider health administration and management elements, which may have a considerable effect on performance and output [40]. These include important, but difficult-to-measure, core competencies, such as strategic thinking and problem-solving; human resources management; financial management; operations management; performance management and accountability; governance and leadership; political analysis and dialog; and community and customer engagement. Several WHO health system assessment tools include proxies for these core competencies (e.g., Health System Performance Assessment, Service Availability and Readiness Assessment) [41]; however, these tools lack assessment of the emergency, trauma, and surgical care system useful for targeted development. While the causes of inefficiency (i.e., high capacity and low output) are certainly multifactorial, improved health administration and management may ensure that available capacity is used more resourcefully. Consequently, future capacity assessments should include proxies for health administration and management core competencies to potentially strengthen their validity.

Beyond the aforementioned additional elements, organizational factors may also play an important role in maximizing output. Nobel Laureate for Economics Amartya Sen theorized on the issue of individual and community utility (i.e., the effect of the use of available resources) and championed the 'human capabilities approach' [42, 43]. The human capabilities approach portends that it is not only the equipment, supplies, knowledge, and skills available that determines our ability to transform resources into valuable activities, but the environment within which we work and the faculty to make useful choices that maximize our utility. In this case, the human capabilities approach would stress that the health system ensure that surgical providers work in an ecosystem that enables and sustains safe and high-volume surgical care regardless of some resource limitations [44].

Although this report offers a useful examination of the relationship between surgical capacity and output, several limitations should be considered prior to drawing conclusions. First, the rating scheme used for the capacity assessment (0–3) was somewhat subjective. In an attempt to strengthen its validity, key informants from several departments within each hospital that interacted with the same resource (e.g., X-ray—emergency room doctors, emergency room nurses, surgeons, nurse anesthetists, X-ray technicians, biomedical engineers) were surveyed about its availability to triangulate responses. Further, direct observation of each resource was performed. Second, two hospitals declined to participate in the study; their resource availability and surgical output may be more or less correlated than was demonstrated at other hospitals;

nonetheless, we have no reason to think that the results from those hospitals would be markedly different. Third, hospitals were not sampled at random, which may have introduced some degree of selection bias. However, our sampling strategy ensured that we included hospitals from each level of the healthcare system and that reflected the variation in surgical capacity, geography (i.e., remoteness, differences in supply chain), and socioeconomic status of the catchment populations. By doing so, the data represent the reality of the use of surgical capacity as a proxy for output. Next, we only collected data on number of surgical specialties available; we did not collect data on the total number of specialists, or their “expertise” beyond their specialty training, including the types of procedures they are comfortable performing or have performed within the last year. While these data may have changed the model to some degree, hospitals that had a surgeon were limited not by number of surgical staff but operating rooms and anesthetists. Therefore, it is unlikely that the addition of these data would have markedly changed the relationship between capacity and output. Lastly, it is likely that institutional differences in recording of procedures led to some information bias; we attempted to minimize this by transcribing data from all possible areas in each hospital that performed procedures (e.g., operating rooms, procedure areas, and emergency units); the study teams did not find evidence for a relationship between capacity and potential differences in recording of procedures. Further, we excluded logbook data that was at high-risk of being discrepantly recorded across hospitals with variable records (i.e., dental and ophthalmologic procedures, which are often performed in a clinic and not recorded in a logbook). Despite the aforementioned limitations, the results from this report allow reasonable conclusions to be drawn about the potentially weak relationship between surgical capacity and output, as well as ways to better evaluate capacity and potentially improve the validity of future assessments.

Conclusions

Contrary to current understanding, surgical capacity assessments are too simplistic may not accurately predict surgical output. To improve the validity of future surgical capacity assessments and facilitate maximal use of available resources, other factors that influence output should also be considered, including:

1. demand-side factors (barriers to care), such as population awareness of surgical need, cost and accessibility of care, ease of healthcare navigation;
2. supply-side factors, such as structure elements (e.g., policies, protocols, incentivization structures, and

process elements), service delivery, and compliance with guidelines and protocols; and

3. health administration and management factors, such as an enabling work environment, emotional infrastructure, financing schemes.

Lastly, there is potentially much to be learned from hospitals with both low efficiency (i.e., high capacity and low output) and high efficiency (i.e., low capacity and high output) that could be used to improve the access to and availability of essential surgical care in low-resource settings.

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Compliance with Ethical Standards

Conflict of interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. Carlson LC, Lin JA, Ameh EA, Mulwafu W, Donkor P, Derbew M et al (2015) Moving from data collection to application: a systematic literature review of surgical capacity assessments and their applications. *World J Surg* 39(813–82):1. <https://doi.org/10.1007/s00268-014-2938-8>
2. Stewart BT, Quansah R, Gyedu A, Boakye G, Abantanga F, Ankomah J et al (2015) Serial assessment of trauma care capacity in Ghana in 2004 and 2014. *JAMA Surg* 2015:1–8
3. Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT et al (2015) Essential surgery: key messages from disease control priorities, 3rd edition. *Lancet* 385:2209–2219
4. Price RI, Makasa E, Hollands M (2015) Strengthening emergency and essential surgical care and anesthesia as a component of universal health coverage—addressing the public health gaps arising from lack of safe, affordable and accessible surgical and anesthetic services. *World J Surg* 39(9):2115–2125. <https://doi.org/10.1007/s00268-015-3153-y>
5. Weiser TG, Regenbogen SE, Thompson KD, Haynes AB, Lipsitz SR, Berry WR et al (2008) An estimation of the global volume of surgery: a modelling strategy based on available data. *Lancet* 372(139–14):4
6. Bolkan HA, Von Schreeb J, Samai MM, Bash-Taqi DA, Kamara TB, Salvessen O et al (2015) Met and unmet needs for surgery in Sierra Leone: a comprehensive, retrospective, countrywide survey from all health care facilities performing operations in 2012. *Surgery* 157:992–1001
7. <http://www.who.int/surgery/publications/s15986e.pdf?ua=1>. 31 Dec 2015

8. Mock C, Lormand J, Goosen J, Joshipura M, Peden M (2004) Guidelines for essential trauma care. World Health Organization, Geneva
9. WHO (2013) WHO generic essential emergency equipment list. In: care Eaes editor Integrated Management for Emergency and Essential Surgical Care (IMEESC) toolkit. World Health Organization, Geneva
10. Osen H, Chang D, Choo S, Perry H, Hesse A, Abantanga F et al (2011) Validation of the World Health Organization tool for situational analysis to assess emergency and essential surgical care at district hospitals in Ghana. *World J Surg* 35(500–50):4. <https://doi.org/10.1007/s00268-010-0918-1>
11. Markin A, Barbero R, Leow JJ, Groen RS, Skow EJ, Apelgren KN et al (2013) A quantitative analysis of surgical capacity in Santa Cruz, Bolivia. *J Surg Res* 185:190–197
12. World_Bank_Group (2014). <http://data.worldbank.org/indicator/NY.GNP.PCAP.CD/countries>. 29 July 2014
13. Zakariah A, Degbotse D, Osei D, Ofosu A, Nyagblornu N, Bjerrum A (2014) Holistic assessment of the health sector programme of work 2013. Ghana Ministry of Health, Accra
14. Stewart BT, Quansah R, Gyedu A, Ankamah J, Donkor P, Mock C (2015) Strategic assessment of trauma care capacity in Ghana. *World J Surg* 39:2428–2440. <https://doi.org/10.1007/s00268-015-3132-3>
15. Gyedu A, Baah EG, Boakye G, Ohene-Yeboah M, Otipiri E, Stewart BT (2015) Quality of referrals for elective surgery at a tertiary care hospital in a developing country: an opportunity for improving timely access to and cost-effectiveness of surgical care. *Int J Surg* 15C(74–7):8
16. Stewart BT, Tansley G, Gyedu A, Ofosu A, Donkor P, Appiah-Denkylira E et al (2016) Mapping population-level spatial access to essential surgical care in Ghana using availability of bellwether procedures. *JAMA Surg* 151(8):e161239. <https://doi.org/10.1001/jamasurg.2016.1239>
17. Ankamah J, Stewart BT, Oppong-Nketia V, Koranteng A, Gyedu A, Quansah R et al (2015) Strategic assessment of the availability of pediatric trauma care equipment, technology and supplies in Ghana. *J Pediatr Surg* 50(11):1922–1927
18. Stewart BT, Tansley G, Gyedu A, Ofosu A, Donkor P, Appiah-Denkylira E et al (2016) Mapping population-level spatial access to essential surgical care in Ghana using availability of bellwether procedures. *JAMA Surg* 151:e161239
19. Debas HT, Donkor P, Gawande A, Jamison DT, Kruk ME, Mock CN (2015) Essential Surgery. In: Jamison DT, Nugent R, Gelband H et al (eds) disease control priorities, 3rd edn. International Bank for Reconstruction and Development/The World Bank, Washington
20. Etikan I, Musa S, Alkassim R (2015) Comparison of convenience sampling and purposive samplings. *Am J Theor Appl Stat* 5:1–4
21. Mock C, Nguyen S, Quansah R, Arreola-Risa C, Viradia R, Joshipura M (2006) Evaluation of trauma care capabilities in four countries using the WHO-IATSIC guidelines for essential trauma care. *World J Surg* 30(946–95):6. <https://doi.org/10.1007/s00268-005-0768-4>
22. Shah MT, Bhattarai S, Lamichhane N, Joshi A, LaBarre P, Joshipura M et al (2015) Assessment of the availability of technology for trauma care in Nepal. *Injury* 46(1712–171):9
23. Shah MT, Joshipura M, Singleton J, LaBarre P, Desai H, Sharma E et al (2014) Assessment of the availability of technology for trauma care in India. *World J Surg* 39(363–37):2. <https://doi.org/10.1007/s00268-014-2805-7>
24. Son NT, Thu NH, Tu NT, Mock C (2007) Assessment of the status of resources for essential trauma care in Hanoi and Khanh Hoa. *Vietnam Inj* 38:1014–1022
25. Daniels KM, Riesel JN, Meara JG (2015) The scale-up of the surgical workforce. *Lancet* 385(Suppl 2):S41
26. Chu KM, Ford NP, Trelles M (2011) Providing surgical care in Somalia: a model of task shifting. *Confl Health* 5:12
27. Bolkan HA, van Duinen A, Waalewijn B, Elhasseim M, Kamara TB, Deen GF et al (2017) Safety, productivity and predicted contribution of a surgical task-sharing programme in Sierra Leone. *Br J Surg* 104:1315–1326
28. Shrimme MG, Verguet S, Johansson KA, Desalegn D, Jamison DT, Kruk ME (2016) Task-sharing or public finance for the expansion of surgical access in rural Ethiopia: an extended cost-effectiveness analysis. *Health Policy Plann* 31(706–71):6
29. Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H et al (2010) Assessment of capacity for surgery, obstetrics and anaesthesia in 17 Ghanaian hospitals using a WHO assessment tool. *Trop Med Int Health TM & IH* 15:1109–1115
30. Linden A, Mantyniemi S (2011) Using the negative binomial distribution to model overdispersion in ecological count data. *Ecology* 92(1414–142):1
31. Lee AH, Wang K, Yau KK, Somerford PJ (2003) Truncated negative binomial mixed regression modelling of ischaemic stroke hospitalizations. *Stat Med* 22(1129–113):9
32. Baker LC, Schoenman JA, Murphy B, Chockley N (2008) The challenges of health system capacity growth. National Institute for Health Care Management (NIHCM) Foundation, Washington
33. Lindsey JK, Jones B (1998) Choosing among generalized linear models applied to medical data. *Stat Med* 17(59–6):8
34. Pourhoseingholi A, Baghban AA, Zayeri F, Alavian SM, Vahedi M (2013) Statistical count models for prognosis the risk factors of hepatitis C. *Gastroenterol Hepatol Bed Bench* 6(41–4):7
35. Stewart BT, Gyedu A, Abantanga F, Abdulai AR, Boakye G, Kushner A (2015) Barriers to essential surgical care in low- and middle-income countries: a pilot study of a comprehensive assessment tool in Ghana. *World J Surg*. <https://doi.org/10.1007/s00268-015-3168-4>
36. Tansley G, Stewart BT, Gyedu A, Boakye G, Lewis D, Hoogerboord M et al (2016) The correlation between poverty and access to essential surgical care in Ghana: a geospatial analysis. *World J Surg*. <https://doi.org/10.1007/s00268-016-3765-x>
37. Nathens AB, Jurkovich GJ, Rivara FP, Maier RV (2000) Effectiveness of state trauma systems in reducing injury-related mortality: a national evaluation. *J Trauma* 48:25–30 (**discussion 30–21**)
38. Stewart BT, Gyedu A, Quansah R, Addo WL, Afoko A, Agbenorku P et al (2015) District-level hospital trauma care audit filters: Delphi technique for defining context-appropriate indicators for quality improvement initiative evaluation in developing countries. *Injury* 47:211–219
39. Lanktree E, Corluka A, Cohen M, Larocque R (2014) Addressing the human resources for health crisis through task-shifting and retention: results from the Africa Health Systems Initiative Support to African Research Partnerships program. *Hum Resour Health* 12(Suppl 1):I2
40. Bradley EH, Taylor LA, Cuellar CJ (2015) Management matters: a leverage point for health systems strengthening in global health. *Int J Health Policy Manag* 4(411–41):5
41. Murray CJ, Frenk J (2000) A framework for assessing the performance of health systems. *Bull World Health Organ* 78(717–73):1
42. Sen A (1979) The tanner lecture on human values. Stanford University, Stanford
43. Sen A (1985) Commodities and capabilities. Oxford University Press, Amsterdam & New York, North-Holland
44. Stewart BT, Editorial Commentary on Bolkan et al (2016) The surgical workforce and surgical provider productivity in Sierra Leone: a countrywide inventory. *World J Surg*. <https://doi.org/10.1007/s00268-016-3417-1>

NEXT STEPS

Contrary to the accepted understanding of the Donebedian framework, the findings from this study suggest that some surgical capacity assessments may not accurately predict surgical output. There are a number of potentially confounding factors that currently go unmeasured, such as demand-side factors (e.g., barriers to care), supply-side factors (e.g., policies and protocols), and broader healthcare system management factors (e.g., incentivization schemes, agency, emotional infrastructure). Future capacity assessments might consider ways to measure these factors and determine if the data improve the validity of the assessments.

In addition to measurement of structure using capacity assessments, trauma systems have relied on measurements of processes and outcomes, particularly in the form of audit filters. Audit filters are specific clinical processes or outcomes of care that, when not met, represent unfavorable deviations from an established norm and which prompt review and feedback. For example, patients with hemorrhagic shock should have early intravenous or intraosseous access and goal-directed volume resuscitation with fluid or blood products. When this does not occur or does not occur frequently, a system or practice review and feedback should occur. Although there are widely accepted audit filters for trauma quality improvement programs in well-resourced systems, there are no context-appropriate audit filters for use in low-resource systems.

To allow measurement of processes and outcomes beyond the structure metrics captured by capacity assessments, we sought to develop context-appropriate trauma care audit filters for hospitals in Ghana and other low-resource settings.

CHAPTER 5 – DISTRICT-LEVEL HOSPITAL TRAUMA CARE AUDIT FILTERS: DELPHI TECHNIQUE FOR DEFINING CONTEXT-APPROPRIATE INDICATORS FOR QUALITY IMPROVEMENT INITIATIVE EVALUATION IN DEVELOPING COUNTRIES

OBJECTIVES

Objective 5. Use the Delphi technique with Ghanaian district-level hospital experienced participants and expert traumatologists to develop consensus on 20 context-specific trauma care audit filters (i.e. data items that serve as proxies for quality trauma care and collective hospital capabilities) that will be used to monitor and evaluate process and quality improvement interventions.

WORK IN CONTEXT

Given the convoluted relationship between capacity and output documented in Chapter 4, we wanted to make available useful metrics of processes to aid in targeted development. To do so, we aimed to generate trauma care audit filters appropriate for Ghanaian and other low-resourced hospitals.

Similar audit filters are used in well-resourced trauma systems to inform quality improvement targets. Additionally, low-resources obstetric care systems have employed audit filters for prospective monitoring and evaluation of maternal and child healthcare. By developing these context-appropriate audit filters for trauma care and integrating their collection into routine data capture and review mechanisms, existing and future quality improvement programs might have access to more meaningful data with which changes in care can be monitored and evaluated beyond capacity alone.

CANDIDATE INVOLVEMENT

The candidate designed the study, sought relevant approvals with assistance from mentoring Professors, collected and managed the data from serial rounds of consensus building, analyzed the data, and drafted the manuscript.

CO-AUTHOR INVOLVEMENT

AG and CM reviewed study design and assisted with introductions and approvals required. Given the study design, all authors assisted in data generation and reviewed the manuscript prior to publication.

ETHICS

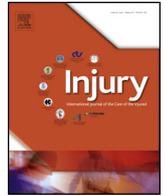
Approvals from Kwame Nkrumah University of Science and Technology and the Ghana Health Service can be found in Appendix 4.1 – 4.2. This study was the first part of a larger study that included a training program and a trauma intake form that included the audit files generated by the study described here. The larger project is not included as part of this dissertation as it was run primarily by a colleague in conjunction with the Ghana Health Service. Stellenbosch University reviewed of all projects herein and found the ethics approvals appropriate. It was determined that the projects were exempt from further review. The letter from Stellenbosch University can be found in Appendix 3.5.



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District-level hospital trauma care audit filters: Delphi technique for defining context-appropriate indicators for quality improvement initiative evaluation in developing countries

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ABSTRACT

Introduction: Prospective clinical audit of trauma care improves outcomes for the injured in high-income countries (HICs). However, equivalent, context-appropriate audit filters for use in low- and middle-income country (LMIC) district-level hospitals have not been well established. We aimed to develop context-appropriate trauma care audit filters for district-level hospitals in Ghana, as well as other LMICs more broadly.

Methods: Consensus on trauma care audit filters was built between twenty panellists using a Delphi technique with four anonymous, iterative surveys designed to elicit: (i) trauma care processes to be measured; (ii) important features of audit filters for the district-level hospital setting; and (iii) potentially useful filters. Filters were ranked on a scale from 0 to 10 (10 being very useful). Consensus was measured with average percent majority opinion (APMO) cut-off rate. Target consensus was defined a priori as: a median rank of ≥ 9 for each filter and an APMO cut-off rate of ≥ 0.8 .

Results: Panellists agreed on trauma care processes to target (e.g. triage, phases of trauma assessment, early referral if needed) and specific features of filters for district-level hospital use (e.g. simplicity, unassuming of resource capacity). APMO cut-off rate increased successively: Round 1 – 0.58; Round 2 – 0.66; Round 3 – 0.76; and Round 4 – 0.82. After Round 4, target consensus on 22 trauma care and referral-specific filters was reached. Example filters include: triage – vital signs are recorded within 15 min of arrival (must include breathing assessment, heart rate, blood pressure, oxygen saturation if

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available); circulation – a large bore IV was placed within 15 min of patient arrival; referral – if referral is activated, the referring clinician and receiving facility communicate by phone or radio prior to transfer. *Conclusion:* This study proposes trauma care audit filters appropriate for LMIC district-level hospitals. Given the successes of similar filters in HICs and obstetric care filters in LMICs, the collection and reporting of prospective trauma care audit filters may be an important step towards improving care for the injured at district-level hospitals in LMICs.

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Introduction

Injuries are responsible for 5 million deaths and incur 52 million disability-adjusted life years annually, comprising 15% of the global disease burden [1]. The urgency of and resource deficiencies for trauma care improvement vary immensely between high-income countries (HICs), where 10% of these deaths occur each year, and low- and middle-income countries (LMICs), where 90% occur [2,3]. Nonetheless, certain tools from trauma care quality improvement in HICs, such as prospective clinical audit, may be useful to LMICs working to reduce avertable death and disability due to injury [4,5].

Given critical resource deficiencies, trauma care improvements should rely on increasing the efficiency and quality of care using low-cost interventions, instead of relying on a bolus of resources [6,7]. Preventable death panel reviews from several LMICs suggest that there is an opportunity to improve trauma care outcomes through low-cost improvements in quality [8]. As example, a tertiary hospital in Brazil found that 61% of in-hospital trauma deaths might have been preventable by meeting trauma care standards [9]. Similarly, a multidisciplinary panel review of traumatic deaths at a tertiary hospital in Ghana found that 60% of deaths were potentially preventable [10]. Similar conclusions from Iran and Pakistan suggest that these findings are not isolated [11,12]. These studies imply that improving the processes of trauma care can prevent death and disability, even in centres with insufficient resources.

In addition to tracking crude or risk-adjusted outcomes (e.g. in-hospital death) or preventable death rates, trauma care can be evaluated by audit filters [13]. Audit filters are routinely tracked actions, processes or expectations of care that can be used to identify when standards are not being met [5,14]. In HICs, routinely collected audit filters are used by trauma centres and systems to evaluate care efficiency and quality [15]. However, commonly used filters assume a high-level of resources (e.g. sufficient and highly trained personnel, timely access to advanced diagnostics) [16]. Given that the assumed level of resources is not appropriate for many LMIC hospitals, these filters are not applicable [3]. While context-appropriate filters have been used successfully for maternal health quality improvement initiatives in LMICs, audit filters useful for monitoring and evaluating trauma care processes are not well established [4,17].

To address this gap, we aimed to use the Delphi technique to develop consensus on trauma care audit filters that would be accurate proxies of quality trauma care, simple to measure and feasible to collect at district-level hospitals in Ghana. By doing so, the proposed filters could be used to benchmark, monitor and evaluate trauma care processes and quality improvement initiatives at first-level hospitals in LMICs more broadly.

Methods

Setting

Ghana is a heavily indebted, lower-middle income country in West Africa with a population of 26 million people and an annual

per capita income of US\$ 1760 [18]. Like other LMICs, the burden of injury is large [2]. The age-standardized injury death rate is 58 per 100,000 persons, which is more than 20% higher than that in HICs [2]. Most injured are brought to the hospital by commercial vehicles, often only after payment [19]. Given long pre-hospital times and lack of care, 80% of trauma deaths occur in the pre-hospital setting [20]. The injured that reach hospital care, particularly those injured in rural areas, almost uniformly encounter facilities without trained trauma teams or essential resources [3]. District-level hospitals are usually the first point of healthcare contact for injured patients; the most senior clinician is usually a medical officer or a non-physician provider [21–23]. Rarely are surgeons or physician anaesthetists available [24]. Nevertheless, many district-level hospitals offer some surgical services, namely caesarean section, and usually have between 50 and 100 beds [23]. As examples of trauma care resource deficiencies, the majority of district-level hospitals in Ghana are unable to provide basic airway support, transfuse blood, take an X-ray or perform a trauma laparotomy for most patients in need, particularly during an emergency [7]. Injuries that require more complex care have to be identified and referred to regional or tertiary hospitals, which face similar resource challenges [7]. Referral often requires prohibitively expensive pre-payment that prevents transfer [25]. Therefore, strengthening district-level trauma care may have greater than expected impact on the avertable death and disability from injury in Ghana given its importance in the ad hoc trauma care system [26].

Delphi technique

We used the Delphi technique to develop consensus on a set of useful district-level hospital trauma care audit filters from panellists with relevant expertise. The Delphi technique is an iterative, anonymous, data-driven survey method that facilitates expert-group consensus building [27]. The four defining characteristics of the Delphi technique are: (i) anonymity; (ii) iteration; (iii) controlled feedback; and (iv) statistical group response [28]. These tenets were upheld throughout the study.

Panellist selection

To ensure that the final trauma care audit filters were both appropriate for the Ghanaian district-level hospital context and represented quality trauma care, we approached experts that met the following criteria: (i) Ghanaian professionals or professionals that have significant experience with the Ghanaian healthcare system; and (ii) expertise in an area relevant to the development of district-level hospital trauma care audit filters. Significant experience was defined as at least 1 year of work in a district-level hospital and/or currently overseeing trauma care at a district-level hospital(s). These areas included trauma care, clinical district-level hospital experience, anaesthesia, nursing, hospital administration, and healthcare policy and evaluation (e.g. Ghana Health Service officials). Obstetricians have been collecting audit filters for maternal care in LMICs for many years [17]; thus, an obstetrician with administrative experience was included. In total, 20 panellists

who met the aforementioned criteria were approached. All approached panellists participated in the Delphi process (i.e. participation rate 100%). The breakdown of the participants' primary area of expertise was as follows:

1. Trauma care – six panellists.
2. District-level hospital care – six panellists.
3. Anaesthesia – one panellist.
4. Nursing – two panellists.
5. Healthcare administration – two panellists.
6. Healthcare policy and evaluation – two panellists.
7. Obstetric care – one panellist.

Note that these represent only primary areas of expertise. Most panellists were able to provide expertise in more than one area (e.g. a surgeon who was also a healthcare administrator and teaches trauma care courses to district hospital staff).

Survey methods

Potential panellists were approached with an email that described the aims of the study, the Delphi technique and expected outputs. This was followed by a telephone communication to ensure the email was received. Potential panellists were asked to respond with a confirmatory email if they wanted to take part; all potential panellists responded. All communication was blinded; none of the panellists knew whom the other panellists were until consensus had been met to avoid social response bias.

For each round, responses to open-ended questions were examined using a content analysis framework [29]. First, qualitative responses were grouped into categories based on codes that represented clustered responses. Then, categories were further refined into useful themes and described. Responses were triangulated between panellists to evaluate the extent of theme convergence. Particularly unique responses were also described and evaluated by panellists in the subsequent survey round.

In addition to open-ended questions, panellists were asked to rank proposed audit filters each round. Filters with a median rank <7 out of 10 were not included in subsequent rounds. Target consensus (i.e. terminating point for the Delphi technique) was defined a priori as: a median rank of ≥ 9 for each proposed audit filter on a scale from 0 to 10 and an average percent majority opinion (APMO) cut-off rate of ≥ 0.8 . The APMO cut-off rate is a consensus measure that is calculated by subtracting agreements from disagreements and dividing the difference by all responses; agreement was defined as an audit filter rank of ≥ 7 [28]. As a sensitivity assessment, consensus was also measured using the coefficient of variance per round and per filter. By doing so, we could evaluate consensus between rounds without having to rely on our definition of agreement (i.e. rank ≥ 7). SurveyMonkey was used for data collection and Stata v12 (College Station, TX, USA) was used for data analysis.

Survey rounds

Round 1 consisted of three parts. Panellists were first asked to propose specific target processes to be measured by the audit filters, as well as important features of filters to be used in the district-hospital setting. Next, panellists were asked to rank a list of potential filters on a scale from 0 to 10 (0 was useless, 5 was somewhat useful and 10 was very useful). Lastly, panellists were asked to propose audit filters to be ranked during the next round.

The findings from Round 1 were presented in Round 2 so that each panellist could consider and evaluate process targets and important features of audit filters offered by other panellists. Panellists were given the opportunity to support, modify or reject

each of the proposed process targets and important features. Next, filters with a median rank of ≥ 7 from the first round, as well as those proposed by the panellists in Round 1, were ranked/re-ranked. Then, open-ended questions regarding highly ranked filters (i.e. median rank ≥ 9) and low ranked filters (i.e. median rank <7) were asked to further understand components of both very useful and less useful filter features. Panellists were again given an opportunity to propose new filters for the next round.

Round 3 was designed to challenge successful filters. First, findings from the previous round were presented and an opportunity was given to support, modify or reject the findings. Second, highly ranked filters from previous rounds and newly proposed filters from Round 2 were grouped into each of the respective district-level hospital-based trauma care categories identified as essential targets by the panellists in Round 1 (e.g. triage, airway, breathing, circulation, disability, exposure/burn, identification of shock, early referral of patients in need of a higher-level of care, resuscitation, reassessment, outcome). Panellists then ranked the grouped filters side-by-side. By doing so, the most useful filter(s) in each trauma care category could be elicited. Additionally, open-ended questions followed each category of filters, which aimed to identify modifications that might improve the filters. Lastly, panellists were again given an opportunity to propose new filters for the next round.

In Round 4, all filters with median rank ≥ 7 in previous rounds and newly proposed filters from Round 3 were ranked/re-ranked within trauma care categories to force panellists to judge one against others that represented same process. Target consensus was reached after Round 4 (i.e. median rank of ≥ 9 for each proposed audit filter and an APMO cut-off rate of ≥ 0.8).

Results

Important processes to measure

Processes that emerged as important targets for monitoring and evaluation included: triage; components of the primary assessment; early identification of shock; early referral of patients in need of a higher-level of care or patients at high-risk for deterioration; resuscitation; reassessment; basic fracture management and a composite measure of care (Table 1).

For hospitals with more resources (i.e. advanced district hospitals, regional or tertiary hospitals) or an established trauma care system, an expanded set of audit filter target processes was agreed upon. These included pre-hospital care, advanced resuscitation, injury diagnostics, timely surgical intervention, life-threatening injury specific filters, and rehabilitation.

Important features of audit filters

Panellists agreed on a number of important features of audit filters for district-level hospitals. These included features related to their accuracy of process measurement, feasibility of data collection, applicability to the district-level hospital setting (i.e. acknowledging differential resource constrains between hospitals) and inclusiveness of facilities regardless of resources to aid comparison. Several particularly informative features are described (Table 2).

Among features most stressed by panellists were simplicity and feasibility, both with regards to the actions expected and data collection mechanism itself. For example, panellists discouraged the use of compound filters (i.e. if 'x', then 'y' was done) or filters that assumed a higher-than-average level of resources (e.g. functioning X-ray, focused assessment with sonography for trauma [FAST] scan training, ability to intubate or operate). Panellists also agreed that the primary aim for trauma care at

Table 1
Trauma care processes that panellists agreed should be monitored by basic and expanded audit filters with examples for district-level hospitals.

Basic	Expanded	Example filter
	Pre-hospital care	Patient arrived by National Ambulance Service
	Time since injury	Patient arrived within 1 h of injury
Triage		Vital signs are recorded within 15 min of patient arrival (must include breathing assessment, heart rate, blood pressure, oxygen saturation if available)
Components of primary assessment		Examination for pneumo- or haemo-thorax was done within 15 min of patient arrival by listening to both sides of the chest with a stethoscope AND bilateral percussion
Identification of shock		If difficulty breathing, OR shock present at triage (HR >100, OR SBP <110) OR oxygen saturation ≤95%, a senior provider (e.g. in-charge, medical officer) is made aware of the patient within 10 min
Identification of patients in need of referral		Referral activation is done within 15 min of detecting or suspecting: free abdominal fluid or haemoperitoneum with no ability to operate (should not delay resuscitation)
Resuscitation	Advanced resuscitation	Basic: A large bore IV was placed within 15 min of patient arrival. Advanced: 2 L of fluid is given to adult patient (or 20 cc/kg for a child) with low blood pressure or tachycardia (as determined by triage vitals)
	Injury diagnostics	If ultrasound machine is present at the hospital, a FAST (focused assessment with sonography for trauma) scan was performed within 30 min of patient arrival
Re-assessment		A second head-to-toe physical exam is performed within 1 h of primary assessment
	Timely surgical intervention	Patient with free abdominal fluid or haemoperitoneum and shock has laparotomy within 2 h
	Life-threatening injury specific	If AVPU is V or P or U AND the patient is not in shock head of the bed is elevated to 45°
Fracture management		Long bone fracture is reduced with analgesia and/or splinted within 2 h of admission or prior to transfer
Comprehensive care		Time and date of referral, discharge or in-hospital death
	Rehabilitation	Patient with a fracture is evaluated by physiotherapist prior to discharge

National Ambulance Service, Ghana has a national ambulance service that is growing to meet the demand for scene responses; HR, heart rate; SBP, systolic blood pressure; IV, intravenous catheter; FAST, focused assessment with sonography for trauma; AVPU, a validated clinical neurological assessment endorsed by the World Health Organization: A is alert, V is responds to voice, P is responds to pain, and U is unresponsive; Proposed audit filters target essential trauma care processes for non-ambulatory patients and those triaged yellow, orange or red using the South African Triage Scale [30].

* Paediatric-specific vital signs representing shock should be available to practitioners and be applied when appropriate.

hospitals without surgical care capacity is to quickly identify and refer patients who are in need of more advanced treatment or at high-risk of deterioration. Therefore, filters that required significant longitudinal data collection (e.g. monitoring of urine output, details of post-resuscitation or post-operative care), while important, were not prioritized. It was also agreed that filters should be useful for comparing all district-level hospitals; however, those with greater resources or an established trauma care system should be able and encouraged to collect a greater number of and/or more advanced filters at their discretion.

Other considerations for audit filters were agreed upon. For example, trauma care audit filters SHOULD:

- align with national trauma care guidelines, as well as internationally accepted standards for trauma care;
- be useful for all potential district-hospital providers (e.g. nurses, non-physician providers, medical officers);
- rely on physical exam and serial assessment rather than diagnostic studies that may or may not be available (e.g. X-ray, lactate determination); and

- be proxies of quality trauma care, not comprehensive checklists.

Additionally, panellists agreed that trauma care audit filters SHOULD NOT:

- require data to be collected on low-risk or low-acuity patients to streamline the care process (e.g. ambulatory patients, those triaged green using the South African Triage Scale) [30];
- inadvertently cause inexperienced staff to perform procedures beyond their scope of practice in an effort to increase the hospital's audit score, which might be more dangerous than early referral (e.g. difficult intubation, trauma laparotomy);
- be linked to a patient's ability or inability to pay;
- neglect the importance of timing and effective triage, but appreciate the large case-loads and insufficient number of staff to manage all of the patients rapidly; and
- underestimate district-level hospital capabilities by setting the bar too low; instead, the bar should be set slightly higher than the current situation but attainable with low-cost quality improvement measures.

Table 2
Important features of district-level hospital trauma care audit filters supported by panellists.

Audit filters SHOULD...	Audit filters SHOULD NOT...
Focus on assessment and early identification of patients that need immediate referral	Rely heavily on resources that may or may not be available to most patients at district-level hospitals (e.g. ability to intubate, perform X-ray or FAST scan, or operate)
Measure early identification and treatment of shock	Include optional actions that do not have proven efficacy or that are not value-added (e.g. haemoglobin assessment)
Be collected mostly during the assessment and resuscitation phase to avoid losses to follow-up once the patient is moved from the casualty ward	Inadvertently cause inexperienced staff to perform procedures that they are not trained to do (e.g. intubation, laparotomy), which could be more dangerous than early referral
Exist within the national framework for trauma and emergency care	Be a burden to collect
Be the same across hospitals for apposite comparison, but be expandable for hospitals with more resources or an established trauma care system	Be a comprehensive checklist of expectations for trauma care
Be useful for nurse, non-physician providers, medical officers and surgeons alike	Reflect a patient's ability to pay for advanced services
Consider the differences in rural versus urban case mix (i.e. rural cases tend to be less severe given most die in the pre-hospital setting; urban cases more often present with severe injuries but alive)	Incorporate the time it takes to get a patient transferred, such as proximity of a vehicle or hospital, gathering payment, etc., but instead reflect timely referral process activation for a patient in need of a higher level of care
Stress early communication between referring and receiving facilities	Rely on technology, which might be broken or insufficient in number at a hospital
Stress the importance of physical exam and serial assessment	Detract resources from other patients who might require similar attention (e.g. obstetric emergencies, paediatric sepsis, etc.)
Be used for all patients, save those who are minimal risk, low-acuity or require minimal treatment (e.g. isolated sport-related injury, simple laceration)	Neglect the importance of timing; however, they must consider hospitals with large case-loads and few human resources to manage all the patients
Be tied into a pre-existing referral activation process	Be collected on low-acuity patients
Focus on common situations, not more rare but serious ones (e.g. electrical injury, urethral injury)	Incorporate more than one step if possible, which might make data collection more difficult if done by a non-clinician
Reflect internationally accepted standards for triage, assessment, and resuscitation in the district-hospital context (e.g. primary trauma care)	Underestimate district-hospital capabilities; filters should set the bar slightly above current care but attainable with quality improvement processes, even with the current level of resources
Be proxies of quality care, not checklists	Be paediatric or adult specific, but universal
Consider late presentations, particularly for burn injury	Require longitudinal data collection (e.g. following urine output)
Include basic data in order to track injury epidemiology and risk-stratify patients for future initiatives	Use GCS; AVPU should be used instead given its simplicity
Include user-friendly data collection forms for non-clinicians	Expect that X-ray or ultrasound exams would be done at bedside

FAST, focused assessment with sonography for trauma; GCS, Glasgow coma scale; AVPU, a validated clinical neurological assessment endorsed by the World Health Organization: A is alert, V is responds to voice, P is responds to pain, and U is unresponsive. Proposed audit filters target essential trauma care processes for non-ambulatory patients and those triaged yellow, orange or red using the South African Triage Scale [30].

Building consensus

In addition to the open-ended questions regarding the target trauma care processes and important features of audit filters at district-level hospitals, specific filters were proposed and ranked in each round. Consensus was measured by APMO cut-off rate with agreement set at rank ≥ 7 on a scale from 0–10, as well as the coefficient of variance.

APMO cut-off rate increased consistently from one round to the next, which demonstrates consensus building: Round 1 – 0.58; Round 2 – 0.66; Round 3 – 0.76; and Round 4 – 0.82 (Fig. 1). Given that all audit filters in Round 4 had a median rank of ≥ 9 and the APMO cut-off rate was ≥ 0.80 , the process was terminated (i.e. target consensus was reached). The sensitivity analysis using coefficient of variance did not depend on a specified level of agreement (i.e. rank ≥ 7). Supporting the finding of consensus using APMO cut-off rate, the coefficient of variance decreased in consecutive rounds from 0.33 in Round 1 to 0.18 in Round 4. These values of both metrics across successive rounds demonstrated improving and strong consensus among panellists.

Consensus was also examined per filter, opposed to per round as above. In Fig. 2, ranked filters are consecutively numbered from

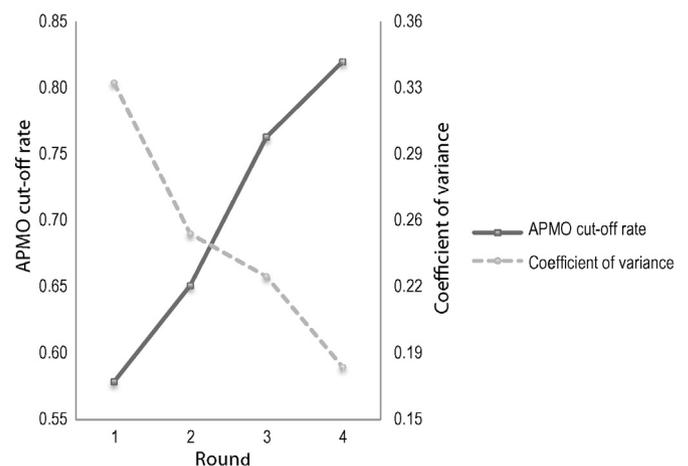


Fig. 1. Average percent of majority opinion (APMO) cut-off rate and coefficient of variance for each round using the Delphi technique. APMO, average percent of majority opinion; Panellist agreement with the audit filter was defined as a median rank of 7 or above. An APMO cut-off rate of 0.80 was selected as a Delphi end-point a priori.

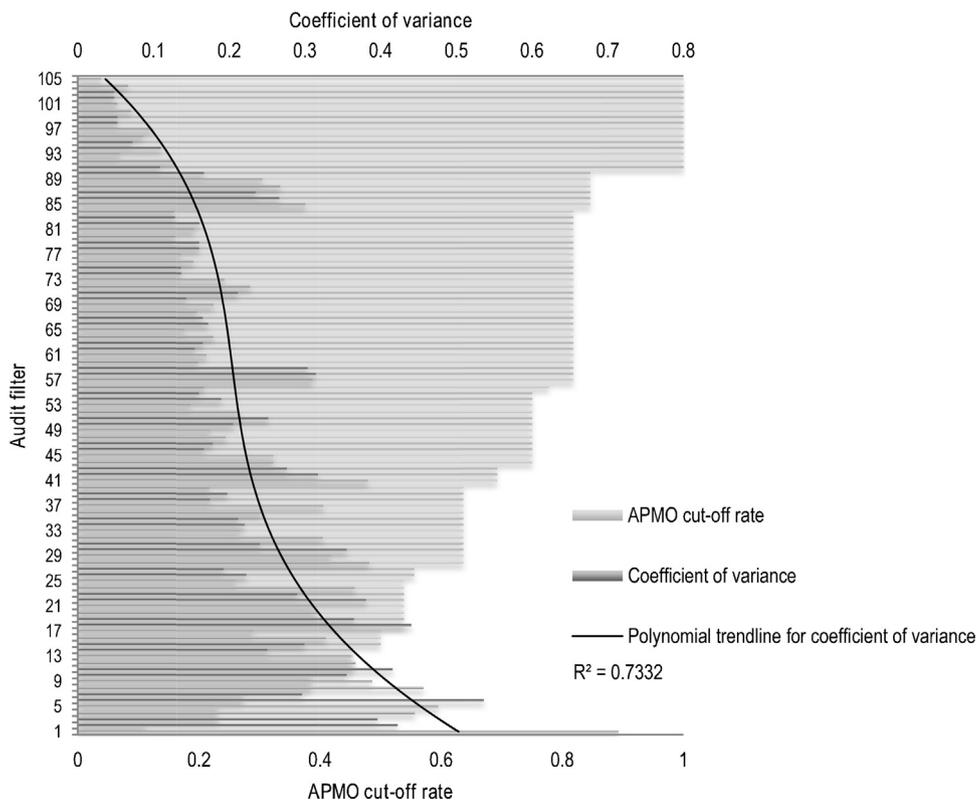


Fig. 2. Average percent of majority opinion (APMO) cut-off rate and coefficient of variance for each audit filter proposed using the Delphi technique. APMO, average percent of majority opinion; Panellist agreement with the audit filter was defined as a median rank of 7 or above. An APMO cut-off rate of 0.80 was selected as a Delphi end-point a priori; Numbers on the y-axis represent consecutively rated audit filters; The 3rd degree polynomial trendline for coefficient of variance was selected based on best fit ($R^2 = 0.73$).

1 to 105. The APMO cut-off rate increased steadily across filters. Consensus within successive filters is demonstrated by the 3rd degree polynomial trendline for coefficient of variance in the same figure ($R^2 = 0.73$).

Audit filters

There were 22 trauma care audit filters agreed upon by the panellists after Round 4; 13 of these are for triage, primary trauma assessment and outcome and 9 are specific to the referral process. The list of audit filters that achieved consensus and the target process of care that they represent are given in [Tables 3 and 4](#). For each of the district-level hospital trauma care processes, there are one or two representative filters. When there are two filters, the first was meant to be more basic or assessment-centred and the second slightly more advanced and action-centred. For example, for evaluation of breathing during the primary assessment, panellists agreed on two filters: (i) examination for pneumo- or haemo-thorax was done within 15 min of patient arrival by listening to both sides of the chest with a stethoscope AND bilateral percussion; and (ii) if pneumo- or haemo-thorax is suspected or confirmed AND oxygen saturation was less than 98%, a chest tube was placed within 30 min of patient arrival. Other examples of audit filters that achieved consensus include:

- If difficulty breathing, OR shock present at triage (HR >100, OR SBP <110)* OR oxygen saturation $\leq 95\%$, a senior provider (e.g. in-charge, medical officer) is made aware of the patient immediately.
- A large bore IV was placed within 15 min of patient arrival.
- Long bone fracture is reduced with analgesia and/or splinted within 2 h of admission or prior to transfer.

The fluid order for a burn patient using the Parkland formula is recorded within 1 h for burns over 15% total body surface area that occurred less than 24 h from patient arrival.

Given the importance of early identification of a patient in need of referral from a district-level hospital, panellists proposed and developed consensus on nine audit filters that reflect quality referral practices. Panellists suggested and agreed that district-level hospitals should have a 'referral activation plan'. This would entail having a pre-designated person(s) quickly make standardized arrangements for transfer to a facility that can provide a higher level of care. Therefore, the clinician taking care of an injured patient can focus his or her attention on the patient without simultaneously trying to coordinate transfer. All of the referral practice audit filters expect that the referral plan would be activated within 15 min of identifying specific injuries or care needs. For example, referral activation is done within 15 min of detecting or suspecting: need for intubation (should not delay intubation if able); or an abnormal neurological exam on two checks 30 min apart (should not delay neuroprotection steps if able). In addition, communication was considered to be particularly important by the panellists. Therefore, a representative audit filter was agreed upon: if referral is activated, the referring clinician and receiving facility communicate by phone or radio prior to transfer.

Discussion

This study used the Delphi technique to develop trauma care audit filters that would be accurate proxies of quality trauma care, simple to measure and feasible to collect at district-level hospitals in Ghana. After four iterative rounds of open-ended questions,

Table 3
District-level hospital trauma care audit filters with panellist consensus using the Delphi technique.

Target process	Proposed audit filter
Triage	<ol style="list-style-type: none"> 1. Vital signs are recorded within 15 min of arrival (must include breathing assessment, heart rate, blood pressure, oxygen saturation if available) 2. If difficulty breathing, OR shock present at triage (HR >100, OR SBP <110)* OR oxygen saturation ≤95%, a senior provider (e.g. in-charge, medical officer) is made aware of the patient immediately
Airway	<ol style="list-style-type: none"> 1. The clinician asked the patient a question and listened for a response to assess airway patency 2. Patient with difficulty or obstructed breathing received basic airway manoeuvre assistance (i.e. sweep, chin-lift-jaw-thrust, oral or nasal airway, suction)
Breathing	<ol style="list-style-type: none"> 1. Examination for pneumo- or haemo-thorax was done within 15 min of patient arrival by listening to both sides of the chest with a stethoscope AND bilateral percussion 2. If pneumo- or haemo-thorax is suspected OR confirmed AND oxygen saturation was less than 98%, a chest tube was placed within 30 min of patient arrival
Circulation	<ol style="list-style-type: none"> 1. A large bore IV was placed within 15 min of patient arrival 2. If there is external bleeding at patient arrival, pressure is applied and maintained until definitive control is performed
Disability	<ol style="list-style-type: none"> 1. If AVPU is not 'A' AND the patient is not in shock, the head of the bed is elevated to 45° 2. Long bone fracture is reduced with analgesia and/or splinted within 2 h of admission or prior to transfer
Exposure	<ol style="list-style-type: none"> 1. Patient is completely undressed, fully examined and covered for privacy within 30 min of arrival 2. The fluid order for a burn patient using the Parkland formula is recorded within 1 h for burns over 15% total body surface area that occurred less than 24 h from patient arrival
Outcome	<ul style="list-style-type: none"> • Date and time and hospital discharge, referral or death

HR, heart rate; SBP, systolic blood pressure;; IV, intravenous catheter; AVPU, a validated clinical neurological assessment endorsed by the World Health Organization: A is alert, V is responds to voice, P is responds to pain, and U is unresponsive. Proposed audit filters target essential trauma care processes for non-ambulatory patients and those triaged yellow, orange or red using the South African Triage Scale [30].

* Paediatric-specific vital signs representing shock should be available to practitioners and be applied when appropriate.

controlled feedback, and filter ranking, 22 filters were agreed upon. The proposed filters aim to measure quality triage, trauma assessment, referral practices and outcomes. These filters represent an important step towards routine, prospective monitoring and evaluation of the trauma care process and/or quality improvement initiatives at first-level hospitals in Ghana, as well as LMICs more broadly.

While trauma care audit filters have been used for a long time to monitor and evaluate care processes at trauma centres and systems in HICs, they have not been used widely in LMICs [14]. Examples of LMIC trauma care audit filter use are namely from larger hospitals in urban centres and/or require resources typically absent at district-level hospitals (e.g. a patient with a Glasgow Coma Scale <13 receives a head computed tomography scan within 2 h of arrival; a patient with an abdominal injury and hypotension receives a laparotomy within 1 h of arrival) [4,5,7]. A study of trauma quality improvement programmes in Asian-Pacific LMICs that included representatives from China, India, Malaysia, Philippines, Sri Lanka, Thailand, and Vietnam reported that no rural hospitals in these countries used audit filters to monitor and evaluate processes of trauma care [4]. Among the reasons for the lack of audit filter use at small hospitals proposed by the authors included a lack of standardized data collection mechanisms, limited resources (i.e. human and physical) and insufficient engagement by local healthcare

Table 4
District-level hospital trauma care audit filters for referral with panellist consensus using the Delphi technique.

Target process	Referral activation is done within 15 min of detecting/suspecting
Airway	<ul style="list-style-type: none"> • Need for intubation (should not delay intubation if able)
Breathing	<ol style="list-style-type: none"> 1. Chest tube needing to be placed (should not prevent a chest tube from being placed if able) 2. Oxygen saturation <92% at any two immediately consecutive checks (should not delay oxygen supplementation, airway assessment or looking for haemo- or pneumo-thorax)
Circulation	<ol style="list-style-type: none"> 1. Free abdominal fluid or haemoperitoneum with no ability to operate (should not delay resuscitation) 2. Pelvic fracture OR two long bone fractures by clinical exam or X-ray (should proceed with reduction and stabilization/splinting as able) 3. Any penetrating injury to the neck, thorax, back or abdomen and no ability to operate
Disability	<ul style="list-style-type: none"> • Abnormal neurological exam on two checks 30 min apart (should not delay neuro-protection steps)
Exposure	<ul style="list-style-type: none"> • Partial thickness burn >15%; circumferential burn; any burn over face, hand, genitals, joint; inhalation injury (resuscitation should proceed as required by history and burn)
Communication	<ul style="list-style-type: none"> • If referral is activated, the referring clinician and receiving facility communicate by phone or radio prior to transfer

Proposed audit filters target essential trauma care processes for non-ambulatory patients and those triaged yellow, orange or red using the South African Triage Scale [30].

leaders [4]. Defining standard, context-appropriate audit filters and obtaining the support of local healthcare leadership are important initial steps to improving trauma care in Ghana, as well as in other LMICs.

Opportunely, obstetric care audit has been performed with success in LMICs [31]. Obstetric audit filters have ranged from composite measurements of quality care (e.g. obstetric case fatality rate, caesarean section rate, proportion of pregnant women receiving antenatal services) to more granular filters that evaluate specific processes of care [17]. Examples of audit filters used for assessing care for obstetric haemorrhage at district-level hospitals include: IV line was established; blood type and cross-match was performed; and oxytocics given and genital tract explored in cases of continuing post-partum haemorrhage [17]. The filters proposed by this study are similar; thus, important lessons for clinical audit of trauma care can be learned from previous development and implementation of audit filters for obstetric care in LMICs.

There are several examples of obstetric clinical audit from LMICs that are particularly useful. In Sierra Leone, obstetric filters were used to evaluate the effectiveness of a capacity improvement package at a district-level hospital that was in need of significant support [31]. The package consisted of two trained physicians with obstetric skills, courses in emergency obstetric care for nurses and midwives, refurbishment of an unused operating theatre, and installation of a generator and blood bank. The hospital tracked the number of obstetric emergencies, obstetric case fatality rate and proportion of abortion-related procedures. The case-fatality rate decreased from 32% to 5% in 5 years despite a tripling in patient volume. However, the ability to identify breakdowns in specific processes of care was not possible; more granular filters were required. Four district-hospitals in Ghana and Jamaica successfully tracked 31 filters that reflected detailed processes of emergency obstetric care (e.g. delivery of the foetus within 2 h of identifying obstructed labour, select lab investigations performed for a woman with severe pre-eclampsia, broad-spectrum antibiotics including metronidazole given for a woman with genital tract sepsis)

[32]. Filters were tracked for 1 year with regular feedback given to hospitals regarding the proportion of successfully completed filters and specific processes that needed improvement. Clinical audit and feedback were able to significantly improve obstetric care (e.g. increase in the proportion of women with obstetric haemorrhage who underwent blood typing and crossmatch – 49–74%; proportion of women treated with antibiotics for genital tract sepsis – 65–93%). These examples from obstetrics demonstrate that clinical audit of trauma care at the district-level hospital is feasible and might allow useful evaluation of the quality of care provided.

District-level hospital referral is an important component of healthcare systems in LMICs [25,33]. Given the global and level-specific lack of resources, almost all patients with one or more serious injury that arrive at district-level hospitals must be transferred [3]. Expectedly, early identification of patients in need of referral, brisk resuscitation and effective inter-facility communication can prevent death and disability [8,34,35]. Therefore, auditing the district-level hospital referral process might be as important as auditing trauma care itself. In Malawi, a referral audit process resulted in significantly improved outcomes for obstetric emergencies [36]. Using audit feedback alone, health facilities were able to improve upon two filters in only 3 months: (i) proportion of adequately resuscitated patients prior to referral; and (ii) delay of less than 2 h from referral activation to arrival at receiving facility. Other filters were audited, but had high compliance at both the initial and repeat assessment, including: (i) all patients referred with referral form; and (ii) short-wave radio communication regarding referral. With the clinical audit examples above and this successful referral audit, the potential utility of audit filters that span the district-hospital trauma care continuum becomes evident.

The way forward regarding the use of these audit filters will require pilot study prior to their implementation. Using feedback from the pilot, the filters might be made user-friendlier and more accurate proxies of trauma care. Subsequently, the number of hospitals taking part would need to be increased, data reported centrally and audit results compared with known levels of quality care to ensure the filters' validity. Should the filters be proven useful, hospital performance should be serially or continuously monitored and evaluated and timely feedback given so that care can be improved [5]. All hospitals in Ghana use a demographic and health information management system (DHIMS-II) to routinely collect and report data to the Ministry of Health [37]. The majority of the indicators used in this system are not granular and none reflect trauma care. To align with DHIMS-II or other national reporting schemes, the proposed filters could be captured on checklist forms and consolidated into a composite metric (e.g. the proportion of successfully performed audit filters per injured person) or into a few filters that are highly correlated with the successful completion of the others. By doing so, trauma care audit filters could be more feasibly collected and included into national healthcare data reporting platforms. Then, quality improvement targets could be identified and strategic interventions evaluated at both the hospital and national levels.

Although this study used a rigorously preformed Delphi technique, there are several limitations that should be considered. First, the filters were developed for the Ghanaian context. However, the human and physical resource limitations known to the panellists are not unique to Ghana [3]. Therefore, these filters are likely generalizable to many other LMIC hospitals, particularly those in sub-Saharan Africa. Given widespread resource deficiencies, the proposed filters might also be useful for primary health centres, and referral and tertiary hospitals in LMICs [7,38]. Second, while the filters were designed to serve as proxies for quality trauma care at the district-level hospital, they may not represent meaningful clinical or patient-centred

outcomes [39]. Piloting of these filters in parallel with routine collection of detailed injury outcome data or from hospitals with known levels of quality will be required for validation. Next, in higher functioning hospitals and as trauma care improves at district-level hospitals, these filters might become too simple to reflect opportunities for quality improvement. Serial revision of the audit filters to maintain contextual appropriateness should be considered. Additionally, as hospitals become more compliant with trauma care standards, the filters' effectiveness as quality improvement tools might decrease [40]. Lastly, these filters are meant to supplement, not replace, other effective and less complex methods of trauma care quality monitoring, such as use of routine morbidity and mortality conferences and multidisciplinary preventable death reviews [5,10]. Despite these limitations, this study has developed potentially useful trauma care audit filters for low-resourced hospitals in Ghana, as well as other LMICs that face similar resource limitations.

Conclusions

This study proposes 22 audit filters that are meant to reflect quality district-level hospital trauma care and referral practices. Quality improvement programmes using these filters might allow hospitals and health care systems to monitor and evaluate hospital-based trauma care. While examples of trauma care audit filters used at district-level hospitals in LMICs are rare, similar filters to the those proposed here have been used extensively by the obstetrics field for benchmarking healthcare facilities and as indicators for quality improvement interventions in LMICs. Given the proven utility of clinical audit to improve care quality in HICs, addition of prospective trauma care audit at district-level hospitals is an important step towards improving care for the injured in LMICs.

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Conflict of interest

No real or potential conflicts to disclose.

References

- [1] GBD Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015;385: 117–71.
- [2] Data visualizations global burden of disease cause patterns. Seattle, WA: Institute of Health Metrics and Evaluation; 2013.
- [3] Wong EG, Gupta S, Deckelbaum DL, Razek T, Kushner AL. Prioritizing injury care: a review of trauma capacity in low and middle-income countries. *J Surg Res* 2015;193(1):217–22.
- [4] Stelfox HT, Joshipura M, Chadbunchachai W, Ellawala RN, O'Reilly G, Nguyen TS, et al. Trauma quality improvement in low and middle income countries of the Asia-Pacific region: a mixed methods study. *World J Surg* 2012;36: 1978–92.
- [5] Mock C, Julliard C, Brundage S, Goosen J, Joshipura M. Guidelines for trauma quality improvement programmes. Geneva: World Health Organization; 2009.
- [6] Peabody JW, Taguiwalo MM, Robalino DA, Frenk J. Disease control priorities in developing countries. 2nd ed. Washington, DC: The International Bank for Reconstruction and Development/The World Bank Group; 2006.
- [7] Stewart B, Quansah R, Gyedu A, Ankomah J, Donkor P, Mock C. Strategic assessment of trauma care technology availability in Ghana. *World J Surg* 2014. in press.
- [8] Mock C, Abantanga F, Goosen J, Joshipura M, Juillard C. Strengthening care of injured children globally. *Bull World Health Organ* 2009;87:382–9.

- [9] da Silva Costa CD, Scarpelini S. Evaluation of the quality of trauma care service through the study of deaths in a tertiary hospital. *Rev Col Bras Cir* 2012;39:249–54.
- [10] Yeboah D, Mock C, Karikari P, Agyei-Baffour P, Donkor P, Ebel B. Minimizing preventable trauma deaths in a limited-resource setting: a test-case of a multidisciplinary panel review approach at the Komfo Anokye Teaching Hospital in Ghana. *World J Surg* 2014;38:1707–12.
- [11] Zafarghandi MR, Modaghegh MH, Roudsari BS. Preventable trauma death in Tehran: an estimate of trauma care quality in teaching hospitals. *J Trauma* 2003;55:459–65.
- [12] Jat AA, Khan MR, Zafar H, Raja AJ, Hoda Q, Rehmani R, et al. Peer review audit of trauma deaths in a developing country. *Asian J Surg/Asian Surg Assoc* 2004;27:58–64.
- [13] MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, et al. A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med* 2006;354:366–78.
- [14] Evans C, Howes D, Pickett W, Dagnone L. Audit filters for improving processes of care and clinical outcomes in trauma systems. *Cochrane Database Syst Rev* 2009;CD7590.
- [15] Glance LG, Dick AW, Mukamel DB, Osler TM. Association between trauma quality indicators and outcomes for injured patients. *Arch Surg* 2012;147:308–15.
- [16] Copes WS, Staz CF, Konvolinka CW, Sacco WJ. American College of Surgeons audit filters: associations with patient outcome and resource utilization. *J Trauma* 1995;38:432–8.
- [17] Graham W, Wagaarachchi P, Penney G, McCaw-Binns A, Antwi KY, Hall MH. Criteria for clinical audit of the quality of hospital-based obstetric care in developing countries. *Bull World Health Organ* 2000;78:614–20.
- [18] CIA. World factbook Ghana. Washington, DC, United States: Central Intelligence Agency; 2014.
- [19] Tiska MA, Adu-Ampofo M, Boakye G, Tuuli L, Mock CN. A model of prehospital trauma training for lay persons devised in Africa. *Emerg Med J – EMJ* 2004;21:237–9.
- [20] Mock C, Jurkovich G, nii-Amon-Kotei D. Trauma mortality patterns in three nations at different economic levels: implications for global trauma system development. *J Trauma* 1998;44:804–14.
- [21] Fulton BD, Scheffler RM, Sparkes SP, Auh EY, Vujicic M, Soucat A. Health workforce skill mix and task shifting in low income countries: a review of recent evidence. *Hum Resour Health* 2011;9:1.
- [22] Ologunde R, Vogel JP, Cherian MN, Sbaiti M, Merialdi M, Yeats J. Assessment of cesarean delivery availability in 26 low- and middle-income countries: a cross-sectional study. *Am J Obstet Gynecol* 2014;211(5):504.
- [23] Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, et al. Assessment of capacity for surgery, obstetrics and anaesthesia in 17 Ghanaian hospitals using a WHO assessment tool. *Trop Med Int Health: TM & IH* 2010;15:1109–15.
- [24] Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, et al. Surgical training and experience of medical officers in Ghana's district hospitals. *Acad Med: J Assoc Am Med Coll* 2011;86:529–33.
- [25] Gyedu A, Baah EG, Boakye G, Ohene-Yeboah M, Otupiri E, Stewart BT. Quality of referrals for elective surgery at a tertiary care hospital in a developing country: an opportunity for improving timely access to and cost-effectiveness of surgical care. *Int J Surg* 2015;15C:74–8.
- [26] Chokotho L, Mulwafu W, Jacobsen KH, Pandit H, Lavy C. The burden of trauma in four rural district hospitals in Malawi: a retrospective review of medical records. *Injury* 2014;45:2065–70.
- [27] Hsu C-C, Sandford BA. The Delphi technique: making sense of consensus practical assessment. *Res Eval* 2007;12:1.
- [28] von der Gracht HA. Consensus measurement in Delphi studies: review and implications for future quality assurance. *Technol Forecast Soc Change* 2012;79:1525–36.
- [29] Bradley EH, Curry LA, Devers KJ. Qualitative data analysis for health services research: developing taxonomy, themes, and theory. *Health Serv Res* 2007;42:1758–72.
- [30] Gottschalk SB, Wood D, DeVries S, Wallis LA, Bruijns S, Cape Triage G. The Cape Triage Score: a new triage system South Africa. Proposal from the Cape Triage Group. *Emerg Med J – EMJ* 2006;23:149–53.
- [31] Leigh B, Kandeh HB, Kanu MS, Kuteh M, Palmer IS, Daoh KS, et al. Improving emergency obstetric care at a district hospital, Makeni Sierra Leone: the Freetown/Makeni PMM team. *Int J Gynaecol Obstet* 1997;59(Suppl 2):S55–65.
- [32] Wagaarachchi PT, Graham WJ, Penney GC, McCaw-Binns A, Yeboah Antwi K, Hall MH. Holding up a mirror: changing obstetric practice through criterion-based clinical audit in developing countries. *Int J Gynaecol Obstet: Off Organ Int Fed Gynaecol Obstet* 2001;74:119–30. discussion 131.
- [33] Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT. Essential surgery: key messages from disease control priorities. 3rd ed. The Lancet; 2015.
- [34] Wisborg T, Montshiwa TR, Mock C. Trauma research in low- and middle-income countries is urgently needed to strengthen the chain of survival. *Scand J Trauma Resusc Emerg Med* 2011;19:62.
- [35] Sa'avu M, Duke T, Matai S. Improving paediatric and neonatal care in rural district hospitals in the highlands of Papua New Guinea: a quality improvement approach. *Paediatr Int Child Health* 2014;34:75–83.
- [36] Kongnyuy EJ, Mlava G, van den Broek N. Criteria-based audit to improve a district referral system in Malawi: a pilot study. *BMC Health Serv Res* 2008;8:190.
- [37] Kayode GA, Amoakoh-Coleman M, Brown-Davies C, Grobbee DE, Agyepong IA, Ansah E, et al. Quantifying the validity of routine neonatal healthcare data in the Greater Accra Region, Ghana. *PLOS ONE* 2014;9:e104053.
- [38] Carlson LC, Lin JA, Ameh EA, Mulwafu W, Donkor P, Derbew M, et al. Moving from data collection to application: a systematic literature review of surgical capacity assessments and their applications. *World J Surg* 2015;39:813–21.
- [39] Willis CD, Gabbe BJ, Cameron PA. Measuring quality in trauma care. *Injury* 2007;38:527–37.
- [40] Jamtvedt G, Young JM, Kristoffersen DT, O'Brien MA, Oxman AD. Does telling people what they have been doing change what they do?. A systematic review of the effects of audit and feedback. *Qual Saf Health Care* 2006;15:433–6.

NEXT STEPS

With the potential for assessments of structure (i.e., using capacity assessments as described in Chapters 2 – 4) and processes and outcomes (i.e., using audit filters described in Chapter 5), the monitoring and evaluation of supply-side issues, particularly those related to trauma care delivery, is relatively robust. However, these metrics do not describe demand-side issues that affect patients' access to safe, timely, and affordable ESTC when needed. Therefore, the next phase of work described in Chapters 6 and 7 explores these issues. In Chapter 6, the development and pilot of a tool to study specific barriers to care is described. Chapter 7 details the population-based spatial access to ESTC.

CHAPTER 6 – BARRIERS TO ESSENTIAL SURGICAL CARE IN LOW- AND MIDDLE-INCOME COUNTRIES: A PILOT STUDY OF A COMPREHENSIVE ASSESSMENT TOOL IN GHANA

OBJECTIVES

Objective 6. Create and pilot a tool to systematically assess barriers to essential surgical care.

WORK IN CONTEXT

Beyond insufficient surgical care capacity, other factors (e.g., barriers to care) prevent patients from receiving surgery. Although there has been a number of reports that describe patient-level barriers to care for a specific condition or type of surgery (e.g., cataract, cleft lip and/or palate, fracture) in low-resource settings, there is not a tool applicable to surgical care broadly. Additionally, many of the existing tools focus on specific barriers, and do not assess the spectrum of obstacles that patients face.

To address this gap, we aimed to develop and pilot a comprehensive, generalizable tool for assessing the barriers to surgical care using a validated framework (i.e., acceptability, accessibility, affordability). The utility of such a tool includes understanding what prevents patients from knowing they have a condition that may benefit from surgery, seeking care, and/or accessing care and using the information to design and monitoring interventions to address barriers to care.

CANDIDATE INVOLVEMENT

The candidate designed the study, sought relevant approvals with assistance from mentoring Professors, supervised the collection of data by trained research assistants, managed the and analyzed the data, and drafted the manuscript.

CO-AUTHOR INVOLVEMENT

FA and AK reviewed the design of the study, assisted with introductions to get approvals for the study, and reviewed the manuscript. AG, ARA, and GB assisted with data collection, reviewed the results and manuscript. All authors approved the final manuscript draft prior to publication.

ETHICS

Approvals from Kwame Nkrumah University of Science and Technology and the Ghana Health Service can be found in Appendix 5.1 – 5.2. Stellenbosch University reviewed of all projects herein and found the ethics approvals appropriate. It was determined that the projects were exempt from further review. The letter from Stellenbosch University can be found in Appendix 3.5.

Barriers to Essential Surgical Care in Low- and Middle-Income Countries: A Pilot Study of a Comprehensive Assessment Tool in Ghana

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Abstract

Background Beyond resource deficiencies, other barriers to care prevent patients from receiving surgery in low- and middle-income countries (LMICs). This study aimed to develop and pilot a comprehensive, generalizable tool for assessing the barriers to surgical care.

Methods Sociodemographic, clinical and 38 questions regarding potential barriers to surgical care were asked during a surgical outreach to two district and one regional hospital in Upper East Region, Ghana. Sites were selected to capture individuals with prolonged unmet surgical needs and represent geographic, socioeconomic, and healthcare development differences. Results were indexed into three dimensions of barriers to care (i.e., ‘acceptability,’ ‘affordability,’ and ‘accessibility’) so that communities could be compared and targeted interventions developed.

Results The tool was administered to 148 participants (98 % response rate): Bolgatanga 54 (37 %); Amiah 16 (11 %); and Sandema 78 (52 %). Amiah had the fewest barriers to surgical care (median index 8.3; IQR 7.6–9.3), followed by Sandema (8.2; IQR 5.3–9.2) and Bolgatanga (6.7; IQR 3.9–9.5). Individual dimension scores (i.e., acceptability, affordability, accessibility) ranged from 10.8 to 18 out of 18 possible points. Main factors contributing to low dimension scores were different between communities: Bolgatanga—cost and healthcare navigation; Amiah—social marginalization and poor medical understanding; Sandema—distance to surgically capable facility.

Conclusion This study identified a number of significant barriers, as well as successes for patients’ ability and willingness to access surgical care that differed between communities. The tool itself was well accepted, easy to administer and provided valuable data from which targeted interventions can be developed.

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Introduction

Conditions that benefit from timely essential surgery account for a considerable proportion of the global disease burden [1, 2]. The majority of this burden falls disproportionately on low- and middle-income countries (LMICs), which are least able to provide necessary care due to deficiencies in surgical capacity [3, 4]. Resultantly, LMICs have a high prevalence of unmet surgical needs, even for common conditions like hernias, hydroceles, fractures, and skin and soft tissue masses [5–7].

In addition to demonstrating critical deficiencies and large disease burdens, assessments of surgical capacity and unmet needs have been important for building an evidence base for advocacy for health systems strengthening and have the potential to garner funding from national and international stakeholders to improve surgical care [8]. However, the addition of necessary surgical inputs (e.g., personnel, perioperative equipment, consumables) in isolation may be inadequate for maximally reducing the avertable burden of surgical disease.

A number of reports have documented a multitude of barriers to surgical care outside of resource deficiencies [9, 10]. Grimes et al. performed a systematic review of barriers to surgical care in LMICs that returned 52 reports describing barriers to care from seven surgical disciplines [9]. They were able to sort the retrieved barriers into 20 themes within three dimensions: acceptability, affordability, and accessibility of surgical care. Importantly, though ophthalmology, emergency care, trauma, obstetrics and gynecology, urology, burns, and breast cancer were represented, there was not a report describing barriers to essential general surgical care in LMICs.

In addition to systemic barriers to care, certain sub-populations have been reported to suffer inordinately from specific barriers that are not significant impediments for the majority of the population, namely children, elderly, women, the uneducated, and religious minorities [10]. However, these often differ considerably between individuals within the same community or country [6, 9–13]. Consequently, efforts to eliminate or minimize barriers to surgical care may require interventions that are tailored to different sub-populations in different communities. Therefore, there is need for a simple, comprehensive, and flexible tool for assessing individual-level barriers to surgical care that can be used to perform a situational analysis or monitor changes over time or after interventions [10].

To address this gap, we aimed to develop and pilot a tool for assessing barriers to surgical care in LMICs that would be easy to administer, simple to analyze, and allow comparison between communities, health systems, and periods of time. We also aimed to examine barriers that might be

unique to general surgical care, as well as those not captured by the proposed tool. In addition to developing a potentially useful tool, these specific results might identify targets for interventions for improving access to surgical care in Upper East Region, Ghana.

Methods

Assessment tool

The assessment tool was developed by creating questions from barriers to surgical care identified by the above-mentioned systematic review using a modified Delphi approach [9, 14]. Modifications to the Delphi approach included the use of a smaller than usual number of expert panelists (i.e., five panelists with experience in developing community-based surveys for LMICs) and not using quantitative methods to include or exclude specific questions for the subsequent round. Instead, the panelists were only given the option of including the question or excluding the question in the next round, as well as offering questions for the group to evaluate. An initial exploration of potential questions and three rounds of questionnaires were used to come to consensus on questions that were thought to accurately represent each theme and be relevant for LMICs and simple to administer [7, 15–18].

The subsequent list of questions was sorted into themes and grouped into the three dimensions reported by the review (Table 1). Additionally, questions that would identify vulnerable sub-populations were included. Ultimately, the tool comprised thirty-eight barrier-specific questions: four vulnerable sub-population identifiers; 21 questions representing acceptability; four questions representing affordability (i.e., direct and indirect costs); and

Table 1 Dimensions and themes surrounding established barriers to surgical care incorporated into the assessment tool [9]

Dimension	Theme
Acceptability	Fear, mistrust
	Marginalized social status
	Level of medical understanding
	Degree of impairment
Affordability	Direct and indirect costs
	Social support
Accessibility	Transportation difficulty
	Delay in diagnosis
	Structural
	Healthcare navigation

nine questions representing accessibility. In addition, name of community and basic clinical information about the presenting problem was asked.

Individual dimension scores (i.e., acceptability, affordability, accessibility) were calculated by adding one point for each item that was not a barrier to care; that number was then multiplied by a dimension factor, which would give each dimension an equivalent score and allow apposite comparison (i.e., making each dimension score out of 18 total points). Next, dimension scores were added together. Lastly, the sum of the dimension scores was indexed on a scale from 0 to 10, where 10 represented no barriers to surgical care (Supplementary Material). Similar indexing methods have been successfully used for surveys of surgical capacity in LMICs [3, 19].

In addition, at the close of the structured portion of the tool, a research team member prompted each patient to consider and discuss other reasons for not receiving timely surgical care that were not captured by prior questions.

Setting

The tool was piloted in three communities that were chosen to represent urban, peri-urban, and rural hospitals and populations from a particularly deprived area in Upper East Region, Ghana during a surgical outreach. ApriDec Medical Outreach Group (AMOG), a Ghanaian-based non-governmental organization (NGO), sponsored the outreach during a 4-day mission in December of 2014. The three sites included: a busy regional hospital in the center of Bolgatanga, the capital of Upper East Region, with constant availability of general surgeons, but strained by high demand; Amiah is a fee-for-service hospital that accepts National Health Insurance Scheme members with a general surgeon that serves patients on the outskirts of Bolgatanga; and a rural district-level hospital in Sandema with that serves individuals from three districts and informal populations near the Burkina Faso border. Staff in Sandema only perform cesarean sections; there is no one available to perform other essential surgical procedures. All three hospitals suffer from severe deficiencies in physical and human resources that have been previously documented in Ghana [20, 21].

Patient sampling and data collection

Community leaders, radio announcements, and visually informative flyers in popular areas (e.g., churches, mosques, markets) were used to mobilize patients to present for surgical care prior to the outreach. Patients were then evaluated and registered by the hospital staff and asked to present during outreach dates for the barriers to care assessment and surgery.

All patients who presented for surgical care were exhaustively sampled. The number of respondents was limited by the effectiveness of the mobilization techniques and the logistics of the surgical outreach (i.e., the number of operations that the volunteers could perform during the 4 days). Given the tool was being piloted for ease of administration, simplicity of analysis and potential comparability between individuals, a pre-specified sample size, and sampling strategy that would accurately represent each community was not necessary.

At each site, three nurses or medical assistants who lived in the respective community and spoke at least one of the local languages (i.e., Buli, Frafra, Nabdom, Hausa, Kusal, Kasem) were selected as research team members to ensure adequate skills for conducting interviews while limiting potential interview bias. Together, all of the local languages were represented. The tool was translated and back translated into each of the local languages to ensure validity of verbal translation by each research team member. In addition, each research team member was trained in the requisite assessment techniques (e.g., questionnaire administration, managing the interview environment and process, active listening, open questioning, reorientation, probing techniques and response scoring) over 2 days. The assessment tool was verbally administered to each patient in his or her primary language prior to pre-operative preparation to avoid perception contamination that might occur after receiving surgical care (i.e., changing one's mind about surgical care after having received an operation, such as fear of anesthesia, surgery, or post-operative pain).

Data analysis

Results from the tool were described and individual dimension scores and the total barrier to care index from each site were calculated using Stata v13 (College Station, Texas). To determine if one or more particularly vulnerable sub-population(s) (i.e., minors or elders, women, those with no education, religious minorities) had an individual index in the lowest quartile, uni- and multi-variable logistic regression were performed [10]. The multi-variable model included each of the a priori defined sub-population covariates, as well as a covariate that represented each community (i.e., Bolgatanga, Amiah, and Sandema) to control for intra-class correlation. There was no evidence for significant multi-collinearity among the covariates in the model ($1.02 < \text{variance inflation factor} < 1.20$; $0.84 < \text{tolerance} < 0.98$). McFadden's pseudo R^2 is reported for assessment of model fit. Responses to the qualitative question were analyzed using content analysis. First, responses were grouped into categories based on codes that represented clustered responses. Then, categories were further refined into useful themes and described.

Ethics

The Kwame Nkrumah University of Science and Technology Committee for Human Research and Publication Ethics, the leadership of AMOG, Regional Health Directorate of the Ghana Health Service and administration of each hospital approved the study.

Adults underwent verbal informed consent after thorough explanation of the assessment process in the patient's primary language. During the consent process, patients were made aware that participation in the survey had no bearing on their potential to receive surgical care. For patients under 18, an adult relative supervising the child's hospital stay provided informed consent. Since a child's access to care is dependent on the parent's or guardian's perceptions and means, questions were directed to that person during the assessment [22].

Results

Demographics and operations

The assessment tool was administered to 148 of the 151 participants approached at the three sites (response rate 98 %): Bolgatanga 54 participants (37 %); Amiah 16 (11 %); and Sandema 78 (52 %). Three patients underwent surgery before being surveyed in Sandema. The median age was 42 years, ranging from 1 to 75 years. Most patients were male (76 %), had not completed any school (66 %) and practiced Christianity, a traditional religion or Islam (Table 2).

The median travel time for patients from their home to Bolgatanga or Sandema was 1 h and was 30 min to Amiah. However, Sandema, being the most rural community and serving several districts, had a travel time interquartile range of 10 min–8 h. The most common condition that patients were having an operation for was hernia and/or hydrocele. Median duration of condition ranged from 36 to 66 months across the sites (IQR 1–240 months) (Table 2).

There was no evidence for any predictive relationship between any of the potentially vulnerable sub-populations (i.e., minors or elders, women, those with no education, religious minorities) and having a barriers to care index in the lowest quartile from the adjusted regression model (pseudo $R^2 = 0.17$) (Table 3).

Barriers to surgical care index

Amiah had the fewest barriers to surgical care and a median index of 8.3 (IQR 7.6–9.3), followed by Sandema (8.2; IQR 5.3–9.2) and Bolgatanga (6.7; IQR 3.9–9.5). Individual

dimension scores (i.e., acceptability, affordability, accessibility) ranged from 10.8 to 18 across the sites (Table 4).

The lowest dimension score in Amiah was acceptability (13.5 out of 18), followed by affordability (15.5; IQR 9.0–18.0). All patients in Amiah reported that there were no accessibility barriers to care (i.e., distance, surgical capable facility, health system navigation). Conversely, patients in Sandema reported that accessibility issues posed the greatest barriers to care (score 14.4; IQR 7.2–14.4). The median dimension score for affordability was 18, suggesting that most patients had no difficulty with direct or indirect costs of care. All dimension scores in Bolgatanga were lower than the other communities. The lowest was for accessibility (10.8; IQR 7.2–18); however, acceptability and affordability were also significant barriers evidenced by dimension scores of 13 and 13.5, respectively (Fig. 1).

Factors contributing to low dimension scores

Figure 2 demonstrates the themes reported by patients as barriers to surgical care for each community; some examples are informative and worth mentioning. In Bolgatanga, 76 % of respondents reported that direct or indirect costs were barriers to care, compared to 44 % in Amiah and 37 % in Sandema. As mentioned above, Bolgatanga also had a low accessibility dimension score; this resulted from respondents having a difficult time navigating the health-care system or receiving a prompt diagnosis (70 %), which were rare barriers in the other two communities.

In Sandema, distance to a facility capable of providing essential surgical care was a barrier for all respondents, compared to 32 % in Bolgatanga and only 13 % in Amiah. Fear or mistrust of the healthcare system or surgery was not a commonly reported barrier in Sandema (8 %), though was reported by more than half of respondents in Bolgatanga and Amiah. In all sites, patients commonly reported not having surgery soon after recognition of their problem because symptoms were not present for a prolonged period of time (56–74 % of respondents across the sites).

Themes not captured by assessment tool

Insufficient health education for surgical conditions was identified as an important barrier to care (Table 5). As example, respondents reported not being aware that hernias could be cured by surgery, that reducible hernias might spontaneously stay reduced, that conditions successfully managed with pain medications do not require surgery, and that, since a lot of community members have hernias or hydroceles that are not repaired, there is no need to have his or her own repaired.

Table 2 Participant demographic information and operations performed at each community in Upper East Region, Ghana

	Bolgatanga		Amiah		Sandema	
	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Participants	54	(37)	16	(11)	78	(52)
Age; median years (IQR)	42	(1–72)	43	(30–54)	42	(4–75)
Male	31	(57)	15	(94)	65	(86)
Education completed						
None	42	(78)	11	(73)	44	(56)
Primary	7	(13)	2	(13)	24	(31)
Secondary	3	(6)	2	(13)	4	(5)
More	2	(4)	0		6	(8)
Religion						
Christian	29	(54)	5	(33)	36	(48)
Traditional	17	(32)	7	(48)	32	(42)
Muslim	7	(13)	3	(20)	6	(8)
Other	1	(2)	0		2	(3)
Travel time; median mins (IQR)	60	(20–180)	30	(20–120)	60	(10–480)
Conditions						
Hernia/hydrocele	30	(57)	15	(94)	65	(84)
Goiter	7	(13)	0		1	(1)
Skin/soft tissue mass	4	(8)	1	(6)	4	(5)
Gynecologic problem	9	(17)	0		2	(3)
Other	3	(6)	0		5	(6)
Duration of problem; median months (IQR)	36	(1–180)	66	(36–108)	36	(6–240)

IQR interquartile range, *mins* minutes

Table 3 Odds ratios for having a barriers to care index in the lowest quartile (i.e., most significant barriers to surgical care) among potentially vulnerable sub-populations of respondents in Upper East Region, Ghana

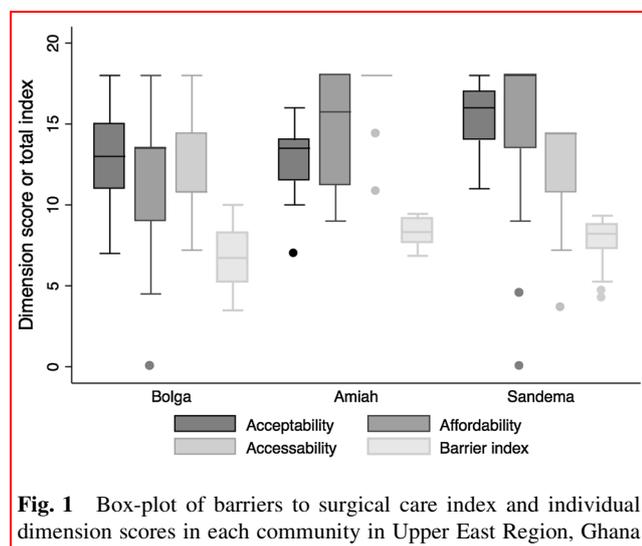
	Odds ratio	(95 % CI)	Adj. odds ratio	(95 % CI)
Age				
≤18 years	Referent		Referent	
19–69 years	1.38	(0.47–4.05)	1.09	(0.34–3.47)
≥70 years	1.54	(0.37–6.38)	1.23	(0.27–5.56)
Sex				
Male	Referent		Referent	
Female	1.24	(0.53–2.91)	1.30	(0.51–3.33)
Education				
None	Referent		Referent	
Any	0.8	(0.37–1.73)	0.62	(0.25–1.49)
Religion				
Christian	Referent		Referent	
Traditional	1.25	(0.56–2.77)	1.46	(0.59–3.63)
Other	0.59	(0.15–2.25)	0.48	(0.12–2.00)

Adj. adjusted odds ratio; the multivariate model included each covariate given their a priori potential for representing vulnerable sub-populations, as well as community to control for intra-class correlation; McFadden's pseudo R^2 for the multi-variable model was 0.17

Table 4 Barriers to surgical care index and individual dimension scores in each community in Upper East Region, Ghana

	Bolgatanga		Amiah		Sandema	
	Median	(IQR)	Median	(IQR)	Median	(IQR)
Barrier index	6.7	(3.9–9.5)	8.3	(7.6–9.3)	8.2	(5.3–9.2)
Acceptability (out of 18)	13.0	(9.0–17.0)	13.5	(11.0–14.0)	16.0	(13.0–18.0)
Affordability (out of 18)	13.5	(0–18)	15.8	(9.0–18.0)	18	(4.5–18)
Accessibility (out of 18)	10.8	(7.2–18)	18	(18–18)	14.4	(7.2–14.4)

IQR interquartile range



Another important barrier to care was perception of safety and quality of surgery provided by local facilities, evidenced by respondents often reporting holding out for an NGO or a surgical mission to have their problem addressed instead of having surgery locally.

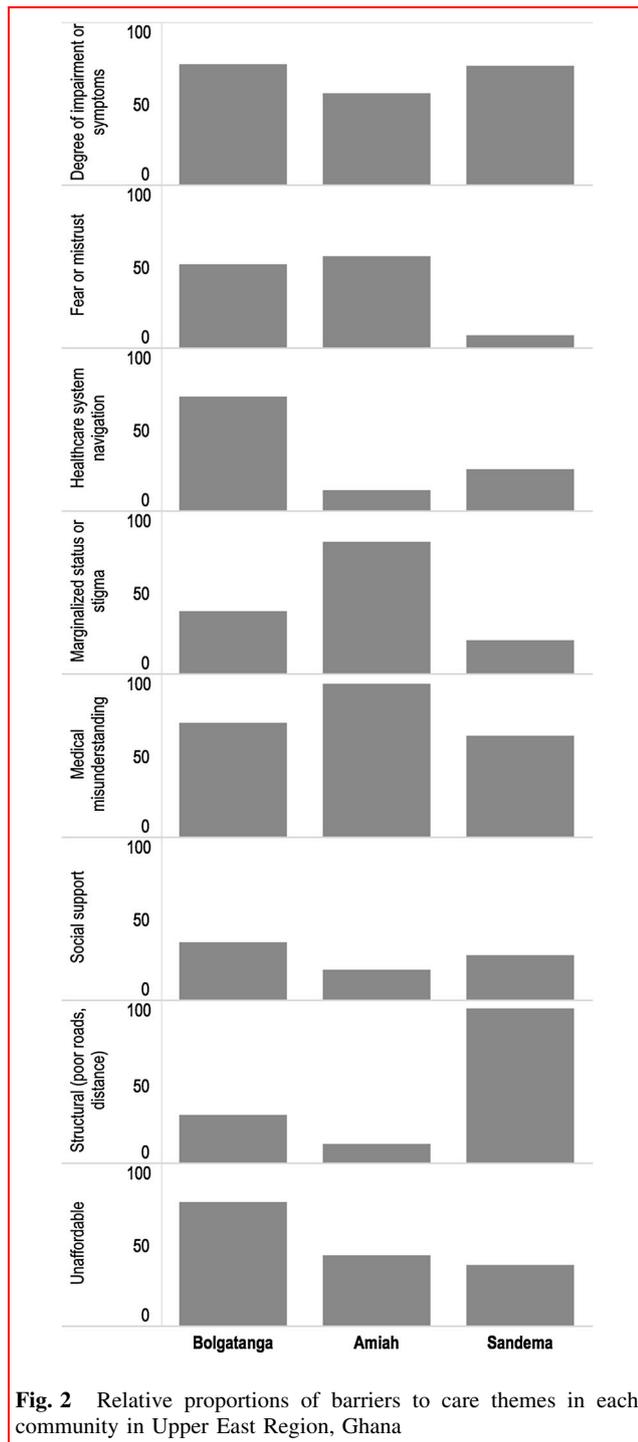
Discussion

This study aimed to develop and pilot a simple, comprehensive, generalizable tool for systematically assessing barriers to surgical care in LMICs. Subsequently, potential targets for health system strengthening interventions could be identified. The tool was easily administered and well accepted by participants. In addition, it allowed global description of the barriers to care at each site and discovery of community-specific barriers that could be targeted for intervention.

The value of systematically assessing barriers to care is that, with consideration of local contexts, the results can inform development of interventions to improve access to surgery. For instance, the lowest dimension score among all sites was accessibility in Bolgatanga (10.8), despite it being a regional capital and having a hospital with

comparatively well-resourced surgical capacity [23]. Given that nearly a quarter of respondents reported difficulty navigating the healthcare system, delayed diagnosis and prolonged referral and waiting times, process analysis and improvement initiatives could result in a substantial reduction in unmet surgical need in that community. In Amiah, 94 % of respondents demonstrated some degree of misunderstanding about their conditions (e.g., a hernia does not lead to emergency, being uninformed about the peri-operative or recovery process, not knowing that a surgical condition can be treated by surgery, seeking cure from traditional healers). Thus, community-based public health education focused on common surgical conditions might improve self-referral and timely surgical care. In Sandema, structural barriers to care were the most commonly reported, namely not having personnel capable of performing more than minor procedures, as well as travel distance. These barriers could be partly alleviated by more adequately resourcing the hospital or providing more frequent surgical outreach to distant communities. As assessments of surgical capacity and unmet needs have demonstrated, national and community surgical health systems vary markedly between one another [6, 24, 25]. There is no reason to suggest that barriers to care are any less heterogeneous. Therefore, improving access to surgical care will require systematic and granular explanation of barriers faced by individuals with surgical conditions within relevant healthcare system catchment areas.

Several categories of other reported barriers to care are not often discussed in the surgical literature. In particular, a number of respondents reported fear of personnel, healthcare system mistrust or wanting to avoid local surgical teams as reasons for not seeking care for their condition. A few respondents waited more than a year to be evaluated by an NGO for their condition instead of seeking treatment or referral by their local hospital. Although there has been a lot of effort focused on improving surgical safety at the district-level hospital, little work has been done to document improvements related to these interventions or translate the safety and effectiveness of district-level surgery to the corresponding communities in need of surgical care [26]. In Nepal, a nation-wide assessment of surgical



need and selected barriers to care discovered that mistrust of the surgical system was the leading cause for not receiving herniorrhaphy [6]. Similar findings for cataract surgery from Myanmar, Kenya, The Gambia, and South Africa suggest that once safe surgery is established, demonstrating that surgical safety and effectiveness to the public is an important and often-overlooked aspect of improving access to surgical care in LMICs [27–30].

Another barrier not often discussed in the surgical literature is community health education. These results demonstrate that individuals have poor understanding of what conditions require surgical evaluation or can be treated with surgery, even for common conditions (e.g., hernias, hydroceles, goiters). Community health activists have dramatically reduced proportions of high-risk communities not tested for HIV, not sleeping under bed nets, not using safe drinking water, or not receiving recommended vaccines with public health promotion strategies [31–34]. However, similar interventions for accessing needed surgical care have not been done. As LMICs continue to make strides in surgical capacity improvements, ensuring that community members understand what needs to be evaluated and treated by surgery will be an important intervention.

Regarding the tool itself, participants accepted the assessment, it was easy to administer and analyze, and provided valuable and granular data from which targeted interventions can be developed. However, further validation of the tool is required, particularly among greater numbers of individuals, women and individuals with different surgical conditions. Additionally, piloting the tool in dissimilar contexts (e.g., communities where social marginalization or structural barriers are known to be barriers to care) would be useful for ensuring validity. Once there is more evidence for the tool's validity, identifying communities that would benefit most from a thorough understanding of local barriers to surgical care will be important, such as those with high surgical disease burden. Further, the tool might be particularly useful for communities that have adequate surgical capacity and a lower than expected surgery case rate. For such areas, it would be important to understand and address non-resource-related barriers that prevent patients from receiving timely surgery. By doing so, local healthcare systems might be able to maximally reduce the avertable burden of surgical disease.

Although this report describes a novel, simple, and comprehensive tool for assessing barriers to surgical care in LMICs, there are several limitations worth consideration prior to interpretation. First, there were relatively few respondents in each community. However, the goal of this study was not to perform an exhaustive assessment of barriers to care at each site. Instead, we aimed to pilot the tool for ease of administration, analysis, and interpretation and identify other barriers to surgical care that should be included in future assessments. Second, there may be a significant difference in barriers to surgical care among persons who did not receive surgery during the outreach and those who did. As has been reported, hospital-based studies do not accurately reflect surgical needs [15, 35]. Similarly, hospital-based assessments of barriers to surgical care may be associated with different barriers than

Table 5 Other barriers to care and resultant themes reported by respondents in Upper East Region, Ghana

Other reasons given for not having timely surgery	Theme
Unaware that a hernia could be cured by surgery	Insufficient health education for surgical conditions
Since the hernia came and went, hoped it would go away entirely	
The hernia was small so it didn't require treatment	
Pain killers made the pain go away so I didn't need surgery	
Lots of people have hernias, they don't get surgery so I thought I didn't have to	
Not registered with the National Health Insurance Scheme, afraid of unforeseen costs	Fear of unknown; costs
Wanted to have surgery done by NGO surgeons, not local clinicians	Perception of safety and quality
Working away from home, didn't want to have surgery there without family around	Need for social support

NGO non-governmental organization

those found by community-based studies. However, participants in this study were aggressively mobilized from their communities by local leaders and dense promotions and reported long durations of disease. Therefore, assessment of this group likely represents an adequate intermediate between the two populations without the resource and time expenditures associated with large population-based studies. Further, selection bias may also exist as a result of differential response to mobilization efforts between rural and urban dwellers, men and women, or those with specific barriers to care (e.g., fear or mistrust). Third, the communities were specifically selected for their geographic, socioeconomic, and healthcare development differences (i.e., rural vs. urban; distinct tribes and lifestyles; district vs. private vs. regional hospital). However, the study was performed in only one region in the north of Ghana. Therefore, prior to considering this tool to be widely generalizable it should be piloted among distinct communities and populations to ensure its validity and external reliability. Next, the majority of the respondents presented with hernia(s) and/or hydrocele(s), thus most were male. Consequently, important gender- or other disease-specific barriers to care may not have been identified. The underrepresentation of women and an array of surgical diseases limit the generalizability of this tool. Another limitation was the use of healthcare workers for administration of the tool, which might have introduced interviewer bias. However, healthcare workers spoke a common language with the research team, had expertise in structured interpersonal interaction useful for rapidly developing the skills required for interviewing (e.g., active listening, redirection, probing techniques), and understood the surgical care context within which this study was rooted. Therefore, the potential interviewer bias might be moderated by these other valuable qualities of healthcare workers. Lastly, this assessment tool was designed to identify individual- and community-level barriers to care. Therefore, other important governance and regulation barriers may exist that were not measured [10]. Nonetheless, these barriers would likely

impact the affordability or accessibility of care, which were captured in detail. Despite these limitations, the results from this pilot study allow reasonable conclusions to be drawn about the presence or absence of significant barriers to surgical care in Upper East Region, Ghana.

Conclusion

The assessment tool was well accepted, easily administered, and provided useful data for planning targeted interventions at the community level. With further piloting, particularly among women and a variety of surgical conditions, the tool may be useful for comparing barriers to surgical care between communities, health systems, and periods of time. With regards to the study findings, a number of significant barriers that require redress were identified. However, several successes for patients' ability and willingness to access surgical care were also discovered. Community-specific barriers to surgical care that could be improved include: improving ease of healthcare navigation and referral at the regional hospital in Bolgatanga; providing community-based health education for common surgical conditions (e.g., hernias, breast masses, fractures) in all sites; and posting a clinician capable of providing essential surgical care in Sandema, or providing surgical outreach to the surrounding rural districts. These specific potential interventions highlight the importance of systematically assessing barriers to surgical care. By doing so, local healthcare systems can identify and minimize the barriers that prevent their residents from receiving timely essential surgical care.

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Compliance with ethical standards

Conflict of interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

- Stewart B, Khanduri P, McCord C et al (2014) Global disease burden of conditions requiring emergency surgery. *Br J Surg* 101:e9–22
- Mock C (2013) Confronting the global burden of surgical disease. *World J Surg* 37:1457–1459. doi:10.1007/s00268-013-2102-x
- Groen RS, Kamara TB, Dixon-Cole R et al (2012) A tool and index to assess surgical capacity in low income countries: an initial implementation in Sierra Leone. *World J Surg* 36:1970–1977. doi:10.1007/s00268-012-1591-3
- Shah MT, Joshipura M, Singleton J et al (2014) Assessment of the availability of technology for trauma care in India. *World J Surg* 39:363–372. doi:10.1007/s00268-014-2805-7
- Groen RS, Samai M, Stewart KA et al (2012) Untreated surgical conditions in Sierra Leone: a cluster randomised, cross-sectional, countrywide survey. *Lancet* 380:1082–1087
- Stewart BT, Pathak J, Gupta S et al (2015) An estimate of hernia prevalence in Nepal from a countrywide community survey. *Int J Surg* 13:111–114
- Petroze RT, Groen RS, Niyonkuru F et al (2013) Estimating operative disease prevalence in a low-income country: results of a nationwide population survey in Rwanda. *Surgery* 153:457–464
- Carlson LC, Lin JA, Ameh EA et al (2015) Moving from data collection to application: a systematic literature review of surgical capacity assessments and their applications. *World J Surg* 39:813–821. doi:10.1007/s00268-014-2938-8
- Grimes CE, Bowman KG, Dodgion CM et al (2011) Systematic review of barriers to surgical care in low-income and middle-income countries. *World J Surg* 35:941–950. doi:10.1007/s00268-011-1010-1
- Irfan FB, Irfan BB, Spiegel DA (2012) Barriers to accessing surgical care in Pakistan: healthcare barrier model and quantitative systematic review. *J Surg Res* 176:84–94
- Hodge A, Byrne A, Morgan A et al (2014) Utilisation of health services and geography: deconstructing regional differences in barriers to facility-based delivery in Nepal. *Matern Child Health J* 19:566–577
- Maslove DM, Mnyusiwalla A, Mills EJ et al (2009) Barriers to the effective treatment and prevention of malaria in Africa: a systematic review of qualitative studies. *BMC Int Health Hum Rights* 9:26
- Phillips KA, Morrison KR, Andersen R et al (1998) Understanding the context of healthcare utilization: assessing environmental and provider-related variables in the behavioral model of utilization. *Health Serv Res* 33:571–596
- Hsu C-C, Sandford BA (2007) The Delphi technique: making sense of consensus. *Pract Assess Res Eval* 12:1–8
- Groen RS, Samai M, Petroze RT et al (2012) Pilot testing of a population-based surgical survey tool in Sierra Leone. *World J Surg* 36:771–774. doi:10.1007/s00268-012-1448-9
- Gupta S, Ranjit A, Shrestha R et al (2014) Surgical needs of Nepal: pilot study of population based survey in Pokhara, Nepal. *World J Surg* 38:3041–3046. doi:10.1007/s00268-014-2753-2
- Gyedu A, Nakua EK, Otopiri E et al (2014) Incidence, characteristics and risk factors for household and neighbourhood injury among young children in semiurban Ghana: a population-based household survey. *Inj Prev* 21(e1):e71–e79
- Osen H, Chang D, Choo S et al (2011) Validation of the World Health Organization tool for situational analysis to assess emergency and essential surgical care at district hospitals in Ghana. *World J Surg* 35:500–504. doi:10.1007/s00268-010-0918-1
- Wong EG, Gupta S, Deckelbaum DL et al (2014) The international assessment of capacity for trauma (INTACT): an index for trauma capacity in low-income countries. *J Surg Res* 190:522–527
- Choo S, Perry H, Hesse AA et al (2010) Assessment of capacity for surgery, obstetrics and anaesthesia in 17 Ghanaian hospitals using a WHO assessment tool. *Trop Med Int Health* 15:1109–1115
- Choo S, Perry H, Hesse AA et al (2011) Surgical training and experience of medical officers in Ghana's district hospitals. *Acad Med* 86:529–533
- Bornstein MH, Britto PR, Nonoyama-Tarumi Y et al (2012) Child development in developing countries: introduction and methods. *Child Dev* 83:16–31
- Stewart BT, Quansah RE, Gyedu A, et al. (2014) Strategic assessment of trauma care technology availability in Ghana, Submitted to peer-review journal
- Mock C, Nguyen S, Quansah R et al (2006) Evaluation of trauma care capabilities in four countries using the WHO-IATSIC Guidelines for Essential Trauma Care. *World J Surg* 30:946–956. doi:10.1007/s00268-005-0768-4
- Markin A, Barbero R, Leow JJ et al (2013) A quantitative analysis of surgical capacity in Santa Cruz, Bolivia. *J Surg Res* 185:190–197
- Haynes AB, Weiser TG, Berry WR et al (2009) A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med* 360:491–499
- Athanasiov PA, Casson RJ, Newland HS et al (2008) Cataract surgical coverage and self-reported barriers to cataract surgery in a rural Myanmar population. *Clin Exp Ophthalmol* 36:521–525
- Briesen S, Geneau R, Roberts H et al (2010) Understanding why patients with cataract refuse free surgery: the influence of rumours in Kenya. *Trop Med Int Health* 15:534–539
- Bowman RJ, Faal H, Jatta B et al (2002) Longitudinal study of trachomatous trichiasis in The Gambia: barriers to acceptance of surgery. *Investig Ophthalmol Vis Sci* 43:936–940
- Rotchford AP, Rotchford KM, Mthethwa LP et al (2002) Reasons for poor cataract surgery uptake—a qualitative study in rural South Africa. *Trop Med Int Health* 7:288–292
- Scott-Sheldon LA, Walstrom P, Harrison A et al (2013) Sexual risk reduction interventions for HIV prevention among South African youth: a meta-analytic review. *Curr HIV Res* 11:549–558
- Njau JD, Stephenson R, Menon M et al (2013) Exploring the impact of targeted distribution of free bed nets on households bed net ownership, socio-economic disparities and childhood malaria infection rates: analysis of national malaria survey data from three sub-Saharan Africa countries. *Malar J* 12:245
- Al-Delaimy AK, Al-Mekhlafi HM, Lim YA et al (2014) Developing and evaluating health education learning package (HELP) to control soil-transmitted helminth infections among Orang Asli children in Malaysia. *Parasites Vectors* 7:416
- Oyo-Ita A, Nwachukwu CE, Oranganje C et al (2011) Interventions for improving coverage of child immunization in low- and middle-income countries. *Cochrane Database Syst Rev* 7:CD008145
- Bickler S, Ozgediz D, Gosselin R et al (2010) Key concepts for estimating the burden of surgical conditions and the unmet need for surgical care. *World J Surg* 34:374–380. doi:10.1007/s00268-009-0261-6

NEXT STEPS

The tool allowed identification of a number of barriers to care, as well as successes regarding patients' ability and willingness to access surgical care. The tool was sensitive enough to detect differences between communities. The tool itself was well accepted, easy to administer and provided valuable data from which targeted interventions could be developed. Among the chief barriers to care was related to geography, transport expenses, and poor road network.

The Lancet Commission on Global Surgery proposed five metrics for national surgical capacity. Among them is the proportion of the population that can reach essential and emergency surgical care within 2 hours. Given the structural barriers to care described by participants of the work within this chapter and to pilot The Lancet Commission geospatial access metric, we proceeded to determine the population-based spatial access to essential surgical care.

CHAPTER 7 – MAPPING POPULATION-LEVEL SPATIAL ACCESS TO ESSENTIAL SURGICAL CARE IN GHANA USING AVAILABILITY OF BELLWETHER PROCEDURES

OBJECTIVES

Objective 7. Perform an assessment of population-level spatial access to essential STC.

WORK IN CONTEXT

Although patients in the barriers to care study described in Chapter 6 signaled that structural barriers were significant, the proportion of patients who can reach emergency and essential surgical care within two hours in Ghana was unknown. The Lancet Commission on Global Surgery recently proposed this metric as a key metric and the concept generally was added to the WHO 100 Core Health Indicators List and The World Bank Health Indicators.^{34, 54}

Therefore, we aimed to: i) assess the performance of bellwether procedures (i.e., open fracture repair, emergency laparotomy, and cesarean section) as proxies for performing essential surgery more broadly; ii) map population-level spatial access to essential surgery; and iii) identify first-level referral hospitals that would most improve access to essential surgery if strengthened in Ghana. By doing so, we could help develop a strategic plan for benchmarking access to essential surgery and targeted capacity building.

CANDIDATE INVOLVEMENT

The candidate designed the study, sought relevant approvals with assistance from mentoring Professors, collected and managed the data with the assistance of Ghana Health Service, analyzed the data with assistance from a geospatial analysis expert, and drafted the manuscript.

CO-AUTHOR INVOLVEMENT

RQ, PD, EAD, DL, JM and CM reviewed the design of the study, assisted with introductions to get approvals for the study, and reviewed the manuscript. AG, GT and AO assisted with data collection, reviewed the results and manuscript. All authors approved the final manuscript draft prior to publication.

ETHICS

Approvals from Kwame Nkrumah University of Science and Technology, the Ghana Health Service, and the University of Washington can be found in Appendix 2.1 – 2.3. Stellenbosch University reviewed of all projects herein and found the ethics approvals appropriate. It was determined that the projects were exempt from further review. The letter from Stellenbosch University can be found in Appendix 3.5.

Original Investigation

Mapping Population-Level Spatial Access to Essential Surgical Care in Ghana Using Availability of Bellwether Procedures

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IMPORTANCE Conditions that can be treated by surgery comprise more than 16% of the global disease burden. However, 5 billion people do not have access to essential surgical care. An estimated 90% of the 87 million disability-adjusted life-years incurred by surgical conditions could be averted by providing access to timely and safe surgery in low-income and middle-income countries. Population-level spatial access to essential surgery in Ghana is not known.

OBJECTIVES To assess the performance of bellwether procedures (ie, open fracture repair, emergency laparotomy, and cesarean section) as a proxy for performing essential surgery more broadly, to map population-level spatial access to essential surgery, and to identify first-level referral hospitals that would most improve access to essential surgery if strengthened in Ghana.

DESIGN, SETTING, AND PARTICIPANTS Population-based study among all households and public and private not-for-profit hospitals in Ghana. Households were represented by georeferenced census data. First-level and second-level referral hospitals managed by the Ministry of Health and all tertiary hospitals were included. Surgical data were collected from January 1 to December 31, 2014.

MAIN OUTCOMES AND MEASURES All procedures performed at first-level referral hospitals in Ghana in 2014 were used to sort each facility into 1 of the following 3 hospital groups: those without capability to perform all 3 bellwether procedures, those that performed 1 to 11 of each procedure, and those that performed at least 12 of each procedure. Candidates for targeted capability improvement were identified by cost-distance and network analysis.

RESULTS Of 155 first-level referral hospitals managed by the Ghana Health Service and the Christian Health Association of Ghana, 123 (79.4%) reported surgical data. Ninety-five (77.2%) did not have the capability in 2014 to perform all 3 bellwether procedures, 24 (19.5%) performed 1 to 11 of each bellwether procedure, and 4 (3.3%) performed at least 12. The essential surgical procedure rate was greater in bellwether procedure-capable first-level referral hospitals than in noncapable hospitals (median, 638; interquartile range, 440-1418 vs 360; interquartile range, 0-896 procedures per 100 000 population; $P = .03$). Population-level spatial access within 2 hours to a hospital that performed 1 to 11 and at least 12 of each bellwether procedure was 83.2% (uncertainty interval [UI], 82.2%-83.4%) and 71.4% (UI, 64.4%-75.0%), respectively. Five hospitals were identified for targeted capability improvement.

CONCLUSIONS AND RELEVANCE Almost 30% of Ghanaians cannot access essential surgery within 2 hours. Bellwether capability is a useful metric for essential surgery more broadly. Similar strategic planning exercises might be useful for other low-income and middle-income countries aiming to improve access to essential surgery.

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Conditions that can be treated by surgery comprise more than 16% of the global disease burden.¹ However, 5 billion people do not have access to essential surgical care, resulting in significant preventable death and disability.² An estimated 90% of the 87 million disability-adjusted life-years incurred by surgical conditions could be averted by providing timely and safe surgical care in low-income and middle-income countries (LMICs).³ However, LMICs are least equipped to provide surgical care.⁴

Providing surgical care is cost-effective and feasible for almost all LMICs with sound planning and organization.³ To guide surgical care capacity building, the third edition of The World Bank's *Disease Control Priorities*⁵ identified 44 surgical procedures as "essential" on the basis that the procedures (1) address a substantial burden of surgical conditions, (2) are highly cost-effective, and (3) are feasible to implement globally, regardless of national income level. Given these attributes, the package of essential surgical care has the potential to provide substantial improvements in population health if it was universally delivered.³

In 2015, the World Health Assembly ratified resolution 68.15: "Strengthening Emergency and Essential Surgical Care and Anesthesia as a Component of Universal Health Coverage."⁶ The resolution calls for member states (ie, countries) to carry out regular monitoring and evaluation of the surgical care capacity of health care facilities and to collect and compile data on the number, type, and indications of surgical procedures performed to guide policy, planning, and development.⁷ To monitor and evaluate interventions to improve essential surgical care capacity and expand access, countries require useful benchmarks.⁸ Several benchmarks have been suggested, such as surgical case rate per population.⁹ The Lancet Commission on Global Surgery¹⁰ suggested that the performance of "bellwether procedures" (ie, open fracture repair, emergency laparotomy, and cesarean section) might be a useful proxy metric for the capability to provide essential surgical care more broadly. However, this assumption has not been well validated.¹¹

Once essential surgical capacity has been assessed countrywide, areas and populations with good and poor access to timely care can be identified. Hospitals with large catchments that do not have the capability to provide essential surgical care could be targeted for capacity improvement. Such an assessment of essential surgical care capability and targeted planning of service expansion has not been performed in an LMIC. To address this gap, we aimed to evaluate first-level referral hospitals' capability to perform essential surgical procedures, validate performance of the bellwether procedures as a proxy for hospitals' capability to perform the breadth of essential surgery, and identify first-level referral hospitals that would most improve population-level spatial access to essential surgery if strengthened in Ghana.

Methods

Setting

Ghana is a heavily indebted, lower-income to middle-income country in West Africa with an annual per capita income of

Key Points

Question What percentage of the population in Ghana can potentially access essential surgical care (measured by hospitals that perform bellwether procedures [ie, open fracture repair, emergency laparotomy, and cesarean section]) within 2 hours?

Findings Population-level spatial access within 2 hours to a hospital that performed 1 to 11 and at least 12 of each bellwether procedure was assessed. Five hospitals were identified for targeted capability improvement.

Meaning Almost 30% of Ghanaians cannot access essential surgery within 2 hours, and similar strategic planning exercises might be useful for other countries aiming to improve access to essential surgery.

US \$1760 and a population of 26 million people.¹² Although predominantly urbanized with several densely populated cities (eg, Accra, Kumasi, and Tamale), 47% of Ghana's population live in rural areas.¹³ Only 13% of the country's 109 515 km of roads are paved, and these thoroughfares are of varying quality.¹³ As proxies for conditions requiring essential surgery, injuries and obstetric emergencies are responsible for 45 and 9 deaths per 100 000 persons per year, respectively.¹⁴ Figures from the United Kingdom, an equivalently sized high-income country, are used for reference, where 82% live in urban centers and 100% of the 398 350 km of roads are paved.¹⁵ Furthermore, there are 36 injury deaths per 100 000 persons annually in the United Kingdom, and obstetric emergency deaths are rare (0.1 per 100 000 persons).¹⁴

First-level referral hospitals in Ghana are usually staffed by a medical officer and nurse anesthetist and have between 50 and 100 beds. Some rural districts do not have a first-level referral hospital and rely on that of a neighboring district. More densely populated districts have several first-level referral hospitals in each of their subdistricts.

Patients requiring more complex care are referred to a larger hospital (ie, 1 of 10 second-level referral hospitals or 1 of 4 tertiary hospitals). In addition, patients who reside, are injured, or become ill near a larger hospital might bypass first-level referral hospitals. Larger hospitals are staffed by a surgery-experienced medical officer, general surgeon, orthopedic surgeon, or obstetrician.

Public and private not-for-profit hospitals support 93% of the hospital beds in Ghana, and private for-profit hospitals comprise 7% of the hospital beds.¹⁶ Care at private for-profit facilities is prohibitively expensive for most of the population.¹⁷ Therefore, such facilities were excluded from this study.

Surgical Data

Surgical data were collected from January 1 to December 31, 2014. The number and type of surgical procedures performed in an operating theater at public and private non-for-profit referral hospitals in Ghana are reported to the Ministry of Health headquarters monthly using the District Health Information Software (DHIS) 2 platform.¹⁸ All procedures performed in 2014 were extracted from the Ministry of Health's

Table 1. Number of Procedures at 123 First-Level Hospitals With and Without Bellwether Procedure Capability in Ghana^a

Variable	First-Level Hospitals, No. (%)	No. of Procedures, Median (IQR)		
		All	Essential	Other
No bellwether procedure capability	95 (77.2)	526 (0-1371)	443 (0-1248)	5 (0-36)
Able to perform 1-11 of each bellwether procedure per year	24 (19.5)	1412 (578-3090) ^b	1157 (510-2569) ^b	123 (30-239) ^b
Able to perform ≥12 of each bellwether procedure per year	4 (3.3)	3582 (2543-5249)	3198 (2365-4716)	384 (178-533)

Abbreviation: IQR, interquartile range.

^a Bellwether procedures include open fracture repair, emergency laparotomy (eg, splenectomy for trauma and repair of hollow viscous perforation), and cesarean section. First-level hospitals were divided into the following 3 groups: (1) those without capability to perform all 3 bellwether procedures, (2) those that performed at least 1 of each bellwether procedure per year, and

(3) those that performed at least 1 of each bellwether procedure per month. Essential surgical procedures were defined in accord with the third edition of The World Bank's *Disease Control Priorities*.⁵

^b $P < .05$ by Wilcoxon rank sum test for equality between the number of procedures performed at bellwether procedure-capable hospital groups and at hospitals without bellwether capability.

database and divided into the following 2 groups: (1) essential surgical procedures as defined by the third edition of The World Bank's *Disease Control Priorities*⁵ and (2) other procedures. Similar data from regional and tertiary facilities are not reported. Ability to perform the bellwether procedures at larger hospitals had been previously determined by visits to each facility and by review of surgical logbooks.⁴

Ethics

This study was approved by the ethical committees of the Kwame Nkrumah University of Science and Technology (Kumasi, Ghana) and the University of Washington (Seattle), as well as by the Ghana Health Service and the Christian Health Association of Ghana.

Validating the Bellwether Procedures

First-level referral hospitals were categorized into the following 3 mutually exclusive groups: (1) those without capability to perform all 3 bellwether procedures, (2) those that performed 1 to 11 of each bellwether procedure per year, and (3) those that performed at least 12 of each bellwether procedure per year. The third group was included a priori by us to avoid inflating the capability in hospitals that intermittently receive surgical outreach teams but do not reliably provide these procedures to those in need^{19,20} and to attempt to highlight higher-volume hospitals because more frequent performance of procedures is highly correlated with safety.²¹

The number of essential surgical procedures performed by hospitals in each group was described. Wilcoxon rank sum test was used to identify differences between the number of essential surgical procedures performed at hospitals within each capability group. In addition, the rate of essential surgical procedures performed per 100 000 persons was calculated using district and submunicipal population data from the 2010 census adjusted to 2015 estimates.²²

Geographic Information Services Data Management

The Ministry of Health provided a list of all hospitals in the country. Hospitals were geolocated using an online application (Google Earth; Google). National population data were represented by a 100-m² gridded population surface generated by the WorldPop²² project, which was created using the 2010 census adjusted to 2015 estimates using United Nations population projections.

We created a national road network by combining data from OpenStreetMap²³ and the Centre for Remote Sensing and Geographic Information Services, University of Ghana, Legon.²⁴ Primary roads (ie, trunk roads connecting major cities) and secondary roads (ie, interregional routes) were obtained from OpenStreetMap. Tertiary roads (ie, minor roads and tracks) were obtained from the Centre for Remote Sensing and Geographic Information Services. After topological verification, travel speed was assigned to each road class based on national traffic laws as 100, 50, and 30 kmh⁻¹ for primary, secondary, and tertiary roads, respectively.^{25,26}

Population Access to Essential Surgical Care

Cost-distance analyses were performed to determine spatial access to essential surgery at all hospital levels countrywide (ie, first-level and second-level referral and tertiary hospitals).²⁷ The "cost" that is implied in the model is not directly financial but is related to time or distance "spent" traveling from one point to another. The cost surface was constructed using the road network and travel speed. Background cells were assigned a value of 5 kmh⁻¹ (ie, average walking speed). The cost surface was superimposed over the country. The value of each cell represented the time required to traverse that cell. The technique resulted in an output that represented the least time-consuming path from any point on the grid to the nearest first-level referral hospital that provided essential surgery (ie, first-level referral hospitals that performed 1-11 or those that performed ≥12 of each bellwether procedure in 2014). The proportion of the population with spatial access to care was evaluated by overlaying the gridded population surface over the cost-distance analyses and calculating the sum of the population within 1 hour and 2 hours of a first-level referral hospital capable of providing essential surgery.

To evaluate model stability, 2 additional cost surfaces were built in which travel speed for each road segment was augmented by ±20%. The analysis was repeated with each of these cost surfaces to create a lower estimate and an upper estimate of the population within each catchment (ie, uncertainty interval [UI]).

Location-Allocation Model

A location-allocation model was built using a software platform (ArcMap, version 10.0; Esri).²⁸ The analysis identified 5 facilities from a candidate list of all first-level referral hospi-

Table 2. Percentage of First-Level Hospitals That Perform Selected Procedures and Bellwether Procedure Capability in Ghana^a

Procedure	No. (%)		
	No Bellwether Procedure Capability (n = 144)	Able to Perform 1-11 of Each Bellwether Procedure per Year (n = 24)	Able to Perform ≥12 of Each Bellwether Procedure per Year (n = 4)
Craniotomy or craniectomy	0 (0.0)	0 (0.0)	1 (25.0)
Skeletal traction placement	0 (0.0)	5 (20.8)	2 (50.0)
Tonsillectomy	0 (0.0)	2 (8.3)	1 (25.0)
Cystoscopy	3 (2.1)	3 (12.5)	1 (25.0)
Nephrectomy	3 (2.1)	1 (4.2)	2 (50.0)
Cholecystectomy	5 (3.5)	7 (29.2)	3 (75.0)
Partial gastrectomy	6 (4.2)	5 (20.8)	3 (75.0)
Sequestrectomy	5 (3.5)	7 (29.2)	1 (25.0)
Splenectomy	6 (4.2)	4 (16.7)	1 (25.0)
Mastectomy	7 (4.9)	6 (25.0)	2 (50.0)
Abdominal tumor resection	8 (5.6)	6 (25.0)	2 (50.0)
Major amputation	9 (6.3)	11 (45.8)	4 (100.0)
Procedure for perianal fistula	10 (6.9)	9 (37.5)	3 (75.0)
Hemorrhoidectomy	12 (8.3)	9 (37.5)	2 (50.0)
Prostatectomy	12 (8.3)	5 (20.8)	4 (100.0)
Orchiectomy	13 (9.0)	15 (62.5)	3 (75.0)
Thyroidectomy	13 (9.0)	10 (41.7)	3 (75.0)
Suprapubic cystostomy	17 (11.8)	7 (29.2)	3 (75.0)
Obstetric fistula repair	17 (11.8)	3 (12.5)	2 (50.0)
Minor amputation	20 (13.9)	16 (66.7)	4 (100.0)
Open reduction and internal fixation	21 (14.6)	13 (54.2)	3 (75.0)
Bartholin gland excision	22 (15.3)	9 (37.5)	3 (75.0)
Closed fracture management	22 (15.3)	17 (70.8)	4 (100.0)
Typhoid perforation	25 (17.4)	12 (50.0)	4 (100.0)
Laparotomy for bowel obstruction	30 (20.8)	14 (58.3)	4 (100.0)
Soft-tissue mass excision	35 (24.3)	18 (75.0)	3 (75.0)
Male circumcision	42 (29.2)	14 (58.3)	4 (100.0)
Uterine myomectomy	43 (29.9)	20 (83.3)	4 (100.0)
Dilation and curettage	52 (36.1)	19 (79.2)	4 (100.0)
Appendectomy	52 (36.1)	20 (83.3)	4 (100.0)
Laparotomy for ectopic pregnancy	55 (38.2)	22 (91.7)	4 (100.0)
Hysterectomy and/or oophorectomy	59 (41.0)	24 (100.0)	4 (100.0)
Herniorrhaphy and/or hydrocelectomy	68 (47.2)	24 (100.0)	4 (100.0)

^a Bellwether procedures include open fracture repair, emergency laparotomy (eg, splenectomy for trauma and repair of hollow viscous perforation), and cesarean section. First-level hospitals were divided into the following 3 groups: (1) those without capability to perform all 3 bellwether procedures, (2) those that performed at least 1 of each bellwether procedure per year, and (3) those that performed at least 1 of each bellwether procedure per month.

tals that performed less than 12 of each bellwether procedure per year that would most improve spatial access to essential surgery if strengthened. Five facilities were chosen as a reasonable starting point for capacity improvement a priori.

The population-weighted geographic centroid of each district represented demand points in the model. A second cost-distance analysis was performed after combining the candidate facilities and facilities that performed at least 12 of each bellwether procedure per year to quantify improvements in population-level spatial access after simulated capability strengthening.

Results

Of 155 first-level referral hospitals managed by the Ghana Health Service and the Christian Health Association of Ghana,

123 (79.4%) reported surgical data. Ninety-five (77.2%) did not have the capability in 2014 to perform all 3 bellwether procedures, 24 (19.5%) performed 1 to 11 of each bellwether procedure, and 4 (3.3%) performed at least 12 (Table 1).

Validating Bellwether Procedures as a Proxy for Essential Surgical Procedure Output

The median number of essential and other surgical procedures was highest in facilities that performed at least 12 of each bellwether procedure (median essential surgical procedures, 3198; interquartile range [IQR], 2365-4716 and median other surgical procedures, 384; IQR, 178-533) (Table 1). Similarly, hospitals that performed 1 to 11 of each bellwether procedure outperformed those without bellwether capability (median essential surgical procedures, 1157; IQR, 510-2569 vs 443; IQR, 0-1248 in hospitals with and

Table 3. Population-Level Spatial Access to Hospitals Capable of Essential Surgery in Ghana^a

Variable	Travel Time ≤1 h, % (Uncertainty Interval)	Travel Time ≤2 h, % (Uncertainty Interval)
First-level hospitals		
Perform 1-11 of each bellwether procedure per year	73.2 (70.0-76.4)	83.2 (81.5-83.3)
Perform ≥12 of each bellwether procedure per year	30.1 (25.1-35.2)	61.7 (52.7-66.0)
First-level and larger hospitals		
Perform 1-11 of each bellwether procedure per year	76.5 (72.2-78.1)	83.2 (82.2-83.4)
Perform ≥12 of each bellwether procedure per year	49.8 (42.1-54.2)	71.4 (64.4-75.0)

^a Bellwether procedures include open fracture repair, emergency laparotomy (eg, splenectomy for trauma and repair of hollow viscous perforation), and cesarean section. First-level hospitals were divided into the following 3 groups: (1) those without capability to perform all 3 bellwether procedures, (2) those that performed at least 1 of each bellwether procedure per year, and (3) those that performed at least 1 of each bellwether procedure per month. Bellwether capability groups are mutually exclusive.

without the capability to perform 1-11 of each bellwether procedure, respectively; $P = .04$).

Table 2 lists the percentages of first-level referral hospitals that performed selected procedures, which consist of both essential and other procedures. Hospitals that performed 1 to 11 of each bellwether procedure consistently performed more types of procedures than hospitals that did not have bellwether capability (22 of 24 [91.7%] selected procedures). Similarly, first-level referral hospitals that performed at least 12 of each bellwether procedure outperformed those that performed fewer bellwether procedures (20 of 24 [83.3%] selected procedures).

Bellwether Capability and Essential Surgical Procedure Rate

The rate of essential surgical procedures performed per 100 000 persons was greater in first-level referral hospitals capable of performing the bellwether procedures than in noncapable hospitals (median, 638; IQR, 440-1418 vs 360; IQR, 0-896 essential surgical procedures per 100 000 persons in hospitals with and without the capability to perform 1-11 of each bellwether procedure, respectively; $P = .03$) (eFigure in the Supplement). The rate was greater still in first-level referral hospital capable of performing at least 12 of each bellwether procedure, although not statistically significantly compared with first-level referral hospitals with capability to perform 1 to 11 of each bellwether procedure (median, 1183; IQR, 675-1603; $P = .31$).

Spatial Access to Essential Surgery

Population-level spatial access within 1 hour and 2 hours to a hospital that performed 1 to 11 of each bellwether procedure was 76.5% (UI, 72.2%-78.1%) and 83.2% (UI, 82.2%-83.4%), respectively (**Table 3** and **Figure 1**). When limited to hospitals that performed at least 12 of each bellwether procedure, spatial access decreased to 49.8% (UI, 42.1%-54.2%) and 71.4% (UI, 64.4%-75.0%) of the population within 1 hour and 2 hours, respectively. Exclusion of larger hospitals (ie, second-level referral and tertiary hospitals) from the analysis of hospitals that

performed at least 12 of each bellwether procedure resulted in a decrease in spatial access to essential surgical care (30.1%; UI, 25.1%-35.2% within 1 hour and 61.7%; UI, 52.7%-66.0% within 2 hours). This finding suggests that larger hospitals are often the nearest facility with essential surgical care capability for much of the population.

Effect of Strengthening First-Level Referral Hospitals

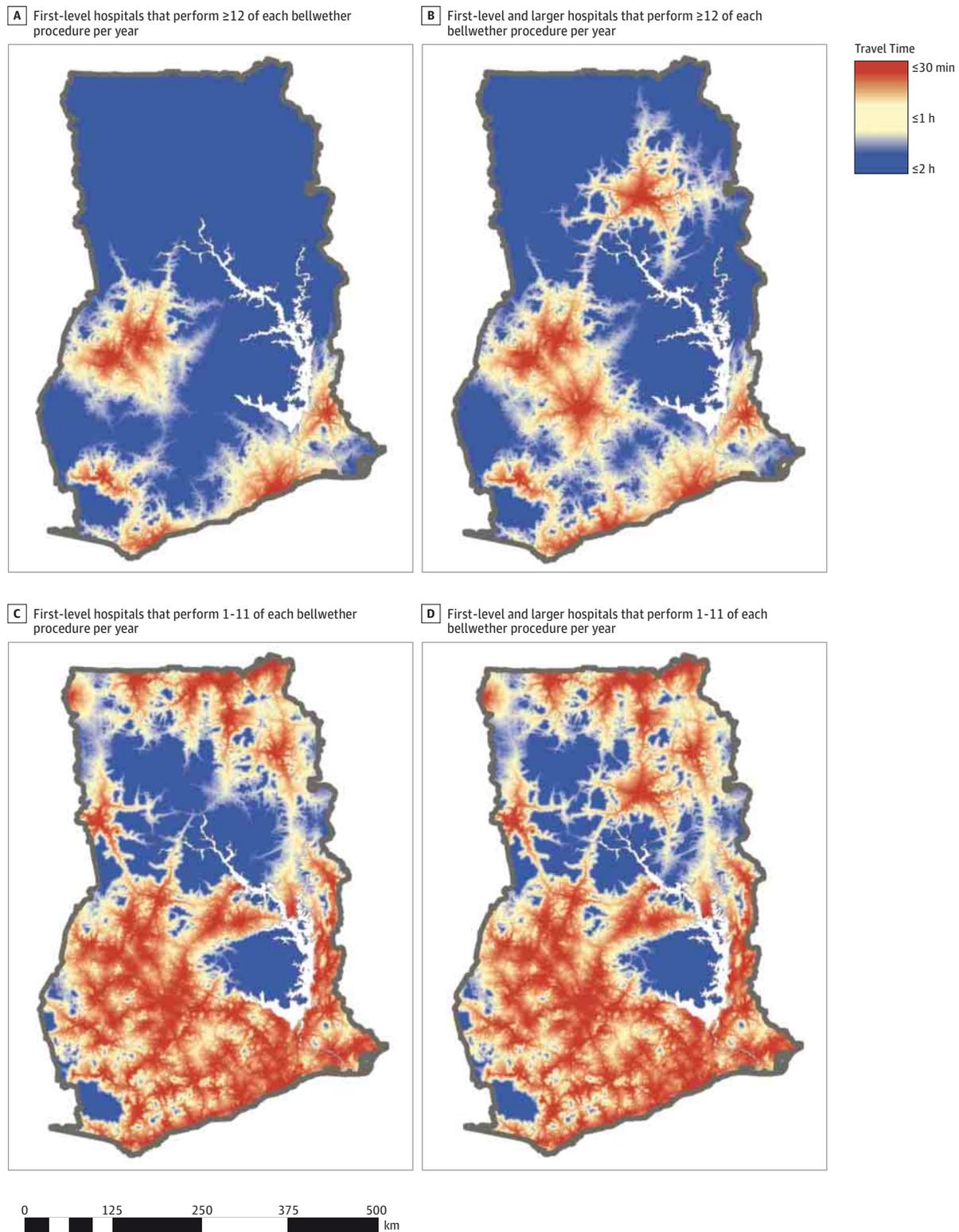
The 5 facilities identified as high-yield candidates for essential surgical care strengthening are shown in **Figure 2**. When the 5 candidates were incorporated into the cost-distance analysis with hospitals that performed at least 12 of each bellwether procedure, population-level spatial access to essential surgical care increased from 30.1% to 60.5% (UI, 52.2%-65.9%) and from 61.7% to 77.3% (UI, 73.4%-78.8%) of the population within 1 hour and 2 hours, respectively.

Discussion

This study aimed to evaluate first-level referral hospitals' capability to perform essential surgery, validate the use of bellwether procedures as a proxy for essential surgical procedure capability more broadly, and identify facilities that would most improve population-level spatial access to essential surgery if strengthened in Ghana. First-level referral hospitals with capability to perform 1 to 11 of each bellwether procedure were significantly more likely to perform a greater number and higher rate of both bellwether and nonbellwether essential surgical procedures than hospitals without bellwether capability. In addition, we demonstrated that almost 30% of Ghanaians are unable to access essential surgery within 2 hours and that larger hospitals are often the nearest capable facilities (ie, not first-level referral hospitals). Last, 5 first-level referral hospitals that would most improve population-level spatial access to essential surgery if strengthened were identified.

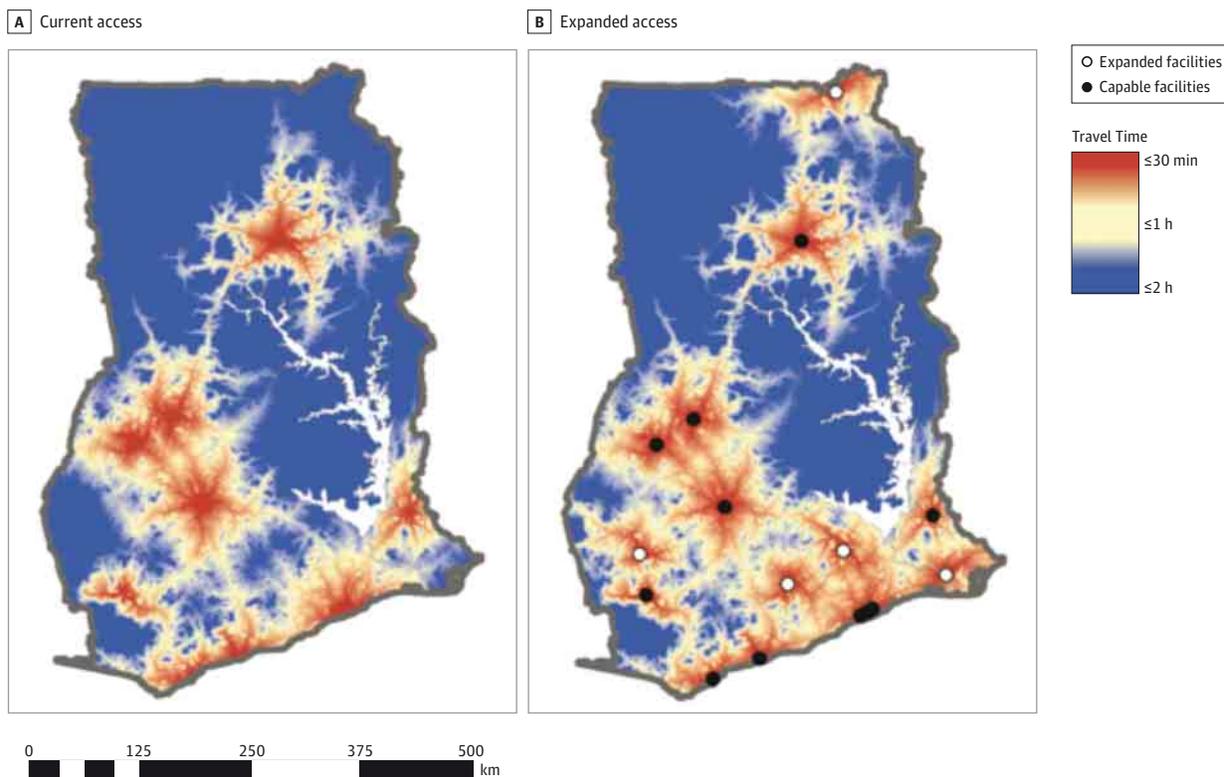
A retrospective analysis of the World Health Organization Global Database for Emergency and Essential Surgical Care, which included data from 1357 facilities in 54 LMICs, demonstrated that at least 50% of bellwether-capable facilities frequently performed a range of other essential surgical procedures.¹¹ While herein both groups (hospitals that performed 1-11 and hospitals that performed ≥12 bellwether procedures) of bellwether-capable first-level referral hospitals performed more procedures than non-bellwether-capable first-level referral hospitals in Ghana, less than 50% of all bellwether-capable hospitals performed a splenectomy, sequestrectomy, or burr hole or placed skeletal traction. Furthermore, the highest essential surgical procedure rate at a first-level referral hospital in Ghana was less than 4000 per 100 000 persons. This rate is significantly less than rates from health care systems that meet surgical demand.²⁹ Therefore, it is likely that there remains a large burden of unmet surgical need in Ghana, even in populations near a bellwether-capable hospital. Thus, investment in essential surgery and capability in improving interventions are needed. Health officials can make use of bellwether capability and essential surgical procedure case rates to monitor changes in essential surgery provision over time.

Figure 1. Cost-Distance Analyses of Population-Level Spatial Access to Essential Surgery in Ghana



Bellwether procedures include open fracture repair, emergency laparotomy (eg, splenectomy for trauma and repair of hollow viscous perforation), and cesarean section.

Figure 2. Cost-Distance Analyses of Population-Level Spatial Access to Essential Surgery With and Without First-Level Hospitals Targeted for Capability Strengthening



A location-allocation model was built to identify 5 facilities in Ghana from a candidate list of first-level hospitals that performed less than 12 of each bellwether procedure per year that would have the greatest effect on population-level spatial access to essential surgery within 1 hour if strengthened. Candidate facilities are Comboni Hospital, Hawa Memorial Savior Hospital, Oda Hospital, Wiawso Hospital, and Zebilla Hospital. Population-weighted geographic centroids of districts represented demand

points in the model. A second cost-distance analysis was performed after combining the candidate facilities and facilities that performed at least 12 of each bellwether procedure per year to quantify improvements in population-level spatial access after capability strengthening. Bellwether procedures include open fracture repair, emergency laparotomy (eg, splenectomy for trauma and repair of hollow viscous perforation), and cesarean section.

From the same analysis of the World Health Organization Global Database for Emergency and Essential Surgical Care aforementioned, the estimated median distance to a bellwether-capable hospital was 35 km.¹¹ Although we went further and described access by travel time, the findings from the present study suggest that population-level spatial access to essential surgical care in Ghana is similar or worse given that only 49% of the population could reach a bellwether-capable first-level referral hospital within 1 hour and almost 30% of the population cannot access safe essential surgical care within 2 hours. Using similar methods, Nesbitt et al³⁰ demonstrated that the mean travel time for pregnant women in Brong Ahafo, one of Ghana's 10 regions, to access a health care facility with comprehensive emergency obstetric care was 28 minutes. Therefore, access to essential surgery in Ghana may lag behind LMIC medians and obstetric care locally. Improving surgical capabilities in first-level referral hospitals identified by the location-allocation model would be an important first step to increasing access to essential surgical care in Ghana and averting otherwise preventable death and disability. Furthermore, the location-allocation modeling analysis could be serially per-

formed to monitor and evaluate the effect of capability improvements on spatial access to essential surgery.

Countries planning to strengthen essential surgical care service delivery can use the modeling exercises demonstrated by this study to explore the relationship between the costs of capacity-building initiatives at 1 or more hospitals (eg, amount of money required to make essential surgical care available at a hospital when needed) and population-level spatial access to care in the countries' context. Given limited funding for surgical care capacity building, the methods described herein may be particularly useful for identifying high-impact facilities to focus available resources.

In addition to relying on the modeling strategy to improve access to care in a cost-efficient manner, health system planners may also consider strengthening surgical care services in hospitals with some existing capacity rather than building capacity from nothing or in facilities without any surgical care services. For example, several of the nonbellwether-capable hospitals herein performed some essential surgical procedures (eg, laparotomy and suprapubic cystostomy), thus demonstrating surgical capacity. Therefore,

they might be ideal targets for comparatively low-cost capability improvements (eg, trauma care training and provision of specific equipment or supplies). However, it must be noted that these findings do not validate bellwether capability as a proxy for subspecialty essential surgical procedures (eg, neurosurgical procedures, cleft lip or palate repair, obstetric fistula repair, cataract extraction, trichiasis surgery, and dentistry). These capabilities should not be overlooked when assessing and improving essential surgery capacity at hospitals, regardless of their bellwether capability. Last, the use of only population-level spatial access gaps to target hospitals for improvement neglects other important considerations, such as reducing nonspatial barriers to surgical care (eg, affordability and acceptability) and prioritizing health equity (eg, improving access to care for particularly marginalized or high-risk populations).^{31,32} The former (reducing nonspatial barriers to surgical care) should be done to ensure that patients are able to access care at a proximate and capable hospital when needed.

While this study describes the first-level referral hospital essential surgery capability countrywide in Ghana and used robust geographic information services methods to identify candidate hospitals for targeted capacity improvement, some limitations should be considered in interpreting the results. First, not all of the first-level referral hospitals in Ghana reported surgical data. The first-level referral hospitals that did not report surgical data were known to not routinely offer operating theater-based surgical care services; therefore, they were analyzed as if they did not have the capability to perform all 3 bellwether procedures. Second, procedure rates at first-level referral hospitals near larger hospitals may be misleading because some patients might have bypassed the first-level referral hospital tier and be effectively excluded from the population denominator. However, we demonstrated that first-level referral hospitals within the catchments of larger hospitals often do not have bellwether capabilities, evidenced by a 39% reduction in spatial access when larger hospitals were excluded from the analysis. Third, this analysis did not incorporate potential variations in prehospital transport mode (eg, private or commercial vehicle or national ambulance service),

traffic patterns, or navigation errors. Although our model was stable with regard to changes in road travel speed, these additional factors might affect spatial access. Fourth, other nonspatial barriers to surgical care exist that prevent people in Ghana from seeking or accessing care.³¹ These other barriers require redress in parallel with strategically increasing the surgical care capacity to achieve maximum population-level benefit. Fifth, we did not consider the locoregional burden of surgical conditions alongside essential surgical capabilities at first-level referral hospitals. Some subpopulations might require a greater essential surgical case rate to meet surgical need than others.³³ However, georeferenced surgical disease burden data are not available for Ghana to date. Despite these limitations, our findings allow reasonable conclusions to be drawn about the lack of essential surgical capacity in Ghana, the validity of using bellwether capability as a proxy for essential surgery capability more broadly, and the first-level referral hospitals that would most improve potential spatial access to essential surgery if strengthened.

Conclusions

Essential surgical capabilities are deficient in Ghana, as evidenced by the finding that 77.2% (95 of 123) of first-level referral hospitals were unable to perform the bellwether procedures. Furthermore, almost 30% of the population cannot access safe essential surgery within 2 hours. For the way forward, we identified 5 first-level referral hospitals where initiatives strengthening surgical care would have the greatest effect on population-level spatial access to essential surgery and should be prioritized. However, nonspatial barriers to surgical care, access to essential subspecialty procedures, and health equity must be considered when planning surgical capability improvement initiatives. Once such initiatives are under way, the frequency and rate of bellwether procedure performance can be used to monitor and evaluate essential surgery more broadly. Similar benchmarking and targeted planning exercises may be useful for other LMICs aiming to improve access to essential surgery.

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REFERENCES

- GBD 2013 Mortality and Causes of Death Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2015;385(9963):117-171.
- Alkire BC, Raykar NP, Shrimel MG, et al. Global access to surgical care: a modelling study. *Lancet Glob Health*. 2015;3(6):e316-e323. doi:10.1016/S2214-109X(15)70115-4.
- Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT; DCP3 Essential Surgery Author Group. Essential surgery: key messages from Disease Control Priorities, 3rd edition. *Lancet*. 2015;385(9983):2209-2219.
- Stewart BT, Quansah R, Gyedu A, Ankomah J, Donkor P, Mock C. Strategic assessment of trauma care capacity in Ghana. *World J Surg*. 2015;39(10):2428-2440.
- Debas HT, Donkor P, Gawande A, Jamison DT, Kruk ME, Mock CN. Essential surgery. In: Jamison DT, Nugent R, Gelband H, Horton S, Jha P, Laxminarayan R, eds. *Disease Control Priorities*. 3rd ed. Washington, DC: International Bank for Reconstruction and Development/The World Bank; 2015.
- Price R, Makasa E, Hollands M. World Health Assembly Resolution WHA68.15: "Strengthening Emergency and Essential Surgical Care and Anesthesia as a Component of Universal Health Coverage"—Addressing the Public Health Gaps Arising from Lack of Safe, Affordable and Accessible Surgical and Anesthetic Services. *World J Surg*. 2015;39(9):2115-2125.
- Stewart BT. Editorial commentary on Bolkan et al: "The Surgical Workforce and Surgical Provider Productivity in Sierra Leone: A Countrywide Inventory" [published online February 23, 2016]. *World J Surg*. 2016.
- Mock C. Confronting the global burden of surgical disease. *World J Surg*. 2013;37(7):1457-1459.
- Stewart B, Wong E, Papillon-Smith J, et al. An analysis of cesarean section and emergency hernia ratios as markers of surgical capacity in low-income countries affected by humanitarian emergencies from 2008-2014 at Médecins Sans Frontières Operations Centre Brussels Projects. *PLoS Curr*. 2015;7:ecurrents.dis.5e30807568eaa09a3e23282ddb41da6. doi:10.1371/currents.dis.5e30807568eaa09a3e23282ddb41da6.
- Gruen R. Lancet Commission in Global Surgery. Information Management Working Group: progress report. <http://www.globalsurgery.info/wp-content/uploads/2013/11/Russel-Gruen.pdf>. Published June 2014. Accessed November 15, 2015.
- Meara JG, Leather AJ, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet*. 2015;386(9993):569-624.
- CIA World Factbook, Ghana. <http://www.cia.gov/library/publications/the-world-factbook/docs/00ad/00ad09a3e23282ddb41da6.html>. Published 2014. Accessed April 12, 2015.
- The World Bank. Ghana: population growth. <http://data.worldbank.org/country/ghana>. Published 2015. Accessed January 14, 2015.
- Global Burden of Disease. Cause patterns. <http://vizhub.healthdata.org/gbd-cause-patterns/>. Updated September 14, 2015. Accessed May 8, 2016.
- The World Bank. United Kingdom. <http://www.worldbank.org/en/country>. Published 2014. Accessed May 6, 2015.
- Ghana Health Service. The health sector in Ghana: facts and figures. http://www.moh-ghana.org/UploadFiles/Publications/GHS%20Facts%20and%20Figures%202010_22APR2012.pdf. Published 2010. Accessed November 15, 2015.
- Amporfu E. Private hospital accreditation and inducement of care under the Ghanaian National Insurance Scheme. *Health Econ Rev*. 2011;1(1):13.
- DHIS 2. Overview. <https://www.dhis2.org/inaction>. Accessed January 12, 2016.
- APRIDEDEC Medical Outreach Group. <http://aprivedec.org/>. Published 2010. Accessed May 12, 2016.
- Sanders DL, Kingsnorth AN. Operation hernia: humanitarian hernia repairs in Ghana. *Hernia*. 2007;11(5):389-391.
- Gawande A, Weiser T, Berry W, et al. *WHO Guidelines for Safe Surgery 2009*. Geneva, Switzerland: World Health Organization; 2009.
- WorldPop. What is WorldPop? <http://www.worldpop.org.uk/>. Published 2015. Accessed July 30, 2015.
- OpenStreetMap. Welcome to OpenStreetMap! <http://www.openstreetmap.org/>. Published 2015. Accessed July 30, 2015.
- CERSGIS. Centre for Remote Sensing and Geographic Information Services, University of Ghana, Legon. <http://www.cersgis.org/>. Published 2015. Accessed July 30, 2015.
- Damsere-Derry J, Afukaar FK, Donkor P, Mock C. Assessment of vehicle speeds on different categories of roadways in Ghana. *Int J Inj Contr Saf Promot*. 2008;15(2):83-91.
- Derry JD, Afukaar FK, Donkor P, Mock C. Study of vehicle speeds on a major highway in Ghana: implication for monitoring and control. *Traffic Inj Prev*. 2007;8(2):142-146.
- Terzi O, Sisman A, Canbaz S, Dündar C, Peksen Y. A geographic information system-based analysis of ambulance station coverage area in Samsun, Turkey. *Singapore Med J*. 2013;54(11):653-658.
- Polo G, Acosta CM, Ferreira F, Dias RA. Location-allocation and accessibility models for improving the spatial planning of public health services. *PLoS One*. 2015;10(3):e0119190. doi:10.1371/journal.pone.0119190.
- Weiser TG, Regenbogen SE, Thompson KD, et al. An estimation of the global volume of surgery: a modelling strategy based on available data. *Lancet*. 2008;372(9633):139-144.
- Nesbitt RC, Gabrysch S, Laub A, et al. Methods to measure potential spatial access to delivery care in low- and middle-income countries: a case study in rural Ghana. *Int J Health Geogr*. 2014;13:25.
- Stewart BT, Gyedu A, Abantanga F, Abdulai AR, Boakye G, Kushner A. Barriers to essential surgical care in low- and middle-income countries: a pilot study of a comprehensive assessment tool in Ghana. *World J Surg*. 2015;39(11):2613-2621.
- Asante AD, Zwi AB, Ho MT. Equity in resource allocation for health: a comparative study of the Ashanti and Northern regions of Ghana. *Health Policy*. 2006;78(2-3):135-148.
- Gupta S, Mahmood U, Gurung S, et al. Burns in Nepal: A population based national assessment. *Burns*. 2015;41(5):1126-1132.

NEXT STEPS

This study highlighted three areas where significant improvements could be made. First, only 23% of first-level hospitals were able to perform the bellwether procedures. In order to bring care to those who need it in a timely fashion, significant efforts need to be concentrated on surgical capacity building at this level. Second, about 30% of the population is unable to reach emergency and essential surgical care within two hours. Although there are some non-healthcare sector factors associated with this (e.g., network and quality of roads), there is much that can be done to reduce and address delays in care, such as building capacity at first-level hospitals, strengthening the pre-hospital care system, and growing lay-person first-aid training programs.

The data from the studies outlined in this and prior chapters have provided a granular understanding of access, barriers to care, capacity, potential metrics, and targets for improvement. However, there is no overarching framework or plan to guide emergency and essential surgical and trauma care development. Therefore, we partnered with the WHO to complete, pilot and refine the Emergency Care System Assessment for use at the national level. This activity would enable us to create a shared vision for EESTC priorities and how to coordinate and develop them in both the short- and long-terms.

CHAPTER 8 – CONSENSUS-BASED ACTION PRIORITIES FROM AN ASSESSMENT OF THE GHANAIAN EMERGENCY CARE SYSTEM

OBJECTIVES

Objective 8. Perform a system-level, consensus-based assessment of the STC system using a novel tool that aims to describe system integration, identify system gaps, and generate a roadmap for development with action priorities for the following domains: organization and governance, financing, data, quality improvement, scene care, transport and transfer, facility-based care, rehabilitation, and emergency and disaster preparedness.

WORK IN CONTEXT

Although we have demonstrated that there has been modest improvements in emergency and surgical care capacity in Ghana since 2004, assessments of access, barriers to care and capacity have demonstrated that there are a number of targets for improvement. However, without a coordinated vision with stakeholders, little gains will be made. The WHO Care System Assessment (ECSA) is a toolkit that would allow us to define national priorities regarding EESTC as they relate to the emergency care system more broadly and create a strategic roadmap for development. At the time of this study, WHO ECSA was not completed and required refinement, pilot testing, and a mechanism for data reporting and visualization. Further, the details and logistics of the study design, stakeholder identification, and data collection processes had not been formalized.

CANDIDATE INVOLVEMENT

The candidate completed the final revisions of the WHO ECSAT, coordinated with the Ghana Ministry of Health, collected and supervised the collection of data, assisted with the data management and semi-automation of data reporting, designed the methods for data analysis, and created the data visualizations for use in the consensus building process. The candidate coordinated and led the consensus building process and wrote the report to the Ghana Ministry of Health.

More specifically, as an intern at WHO Headquarters in Geneva, I was given the opportunity to take feedback from experts within the African Federation of Emergency Medicine, Western Pacific Regional stakeholders, and Ghanaian clinicians and policy-makers and finalize the ECSA. We then were tasked with the first national pilot of the ECSA, including: selecting stakeholders with input from the Ghana Ministry of Health, collecting data, streamlining cloud-based data management, generating semi-automated reports and data visualizations, creating a consensus and a development roadmap, and disseminating the findings to key stakeholders and partners. The Ghana Ministry of Health was engaged with the process, but as this was a pilot, did not perform any of the study design, data collection or coordination of activities surrounding the ECSA.

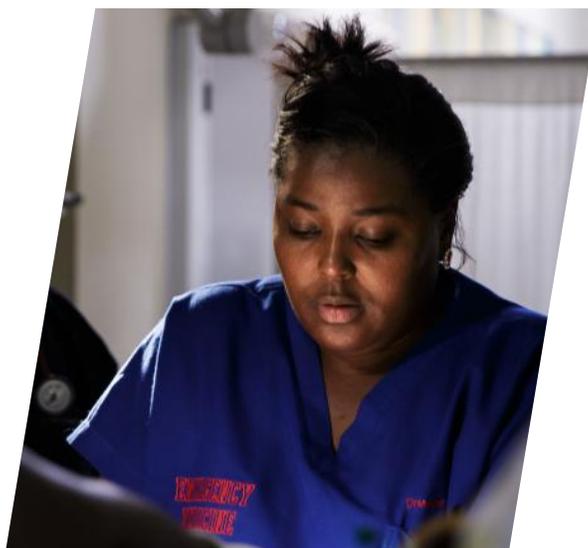
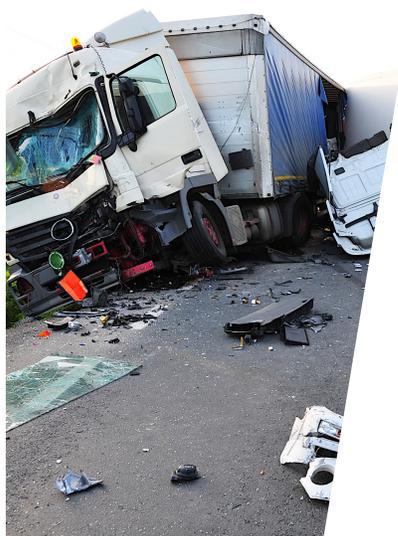
CO-AUTHOR INVOLVEMENT

AG and RQ provided significant help with coordination of the working group. Given the nature of the study, data collection was done by all participants and co-authors. All authors approved the final manuscript draft prior to publication; their names are listed in the report.

ETHICS

Approvals from Kwame Nkrumah University of Science and Technology and the Ghana Health Service can be found in Appendix 6.1 – 6.2. Stellenbosch University reviewed of all projects herein and found the ethics approvals appropriate. It was determined that the projects were exempt from further review. The letter from Stellenbosch University can be found in Appendix 3.5.

CONSENSUS-BASED ACTION PRIORITIES FROM AN ASSESSMENT OF THE GHANA EMERGENCY CARE SYSTEM



In collaboration with: Ghana Red Cross Society; National Police Service; National Fire Service; National Disaster Management Organisation; National Road Safety Commission; Nursing and Midwifery Council; 1mCHW Ghana; Community-based Health Planning and Service; Kwame Nkrumah University of Science and Technology; University of Cape Coast; AO Foundation Ghana; Department for the Management of NCDs, Disability, Violence and Injury Prevention, World Health Organization, Geneva; and emergency departments of Korle Bu Teaching Hospital, Komfo Anokye Teaching Hospital, and Tamale Teaching Hospital.

EXECUTIVE SUMMARY

Emergency care systems address a wide-range of common medical, surgical, and obstetric conditions, including injury, complications of pregnancy, exacerbations of non-communicable diseases (e.g. asthma, heart attacks, strokes), and acute infections (e.g. sepsis, malaria).¹ With sound planning and organisation, emergency care systems have the potential to address nearly half of deaths and more than a third of disability annually in low- and middle-income countries (LMICs).^{2,3}

There have been modest improvements in emergency care capacity over the last decade in Ghana. Nonetheless, a number of recent population-level access and prehospital- and facility-based assessments have demonstrated: poor access to emergency care for the majority of the population;^{4,5} critical deficiencies in essential resources;^{4,6-8} insufficient training;⁸⁻¹¹ and lack of organisation.¹²

Given the potential to reduce death and disability from emergency conditions in Ghana through improvements in the emergency care system, the Ghana Health Service (GHS) teamed up with Kwame Nkrumah University of Science and Technology and World Health Organization's (WHO) Emergency, Trauma and Acute Care programme to conduct a system-level assessment of emergency care and organize a working group composed predominantly of local experts in the emergency care system.

The GHS approached key stakeholders and asked them to complete the WHO Emergency Care System Assessment Tool (ECSAT). The WHO ECSAT is a survey that was developed to identify strengths and weaknesses of national emergency care systems. The responses were compiled and a working group was convened on March 21st - 22nd, 2016 by the GHS to review the results and develop consensus-based action priorities. Representatives from the major groups dealing with emergency care in Ghana were represented, including: Ghana Red Cross Society, National Police Service, National Fire Service, National Disaster Management Organisation, National Road Safety Commission, Nursing and Midwifery Council, 1mCHW Ghana, Community-based Health Planning and Service, all levels of facility-based care (e.g., primary health centres, district hospitals, regional hospitals, teaching hospitals), emergency medicine training programs, AO Foundation. The action priorities for each component of the emergency care system proposed by the working group are listed below. Action priorities in bold represent those that are high-yield, feasible in the near-term and/or would require only minimal added resources.

SYSTEM ORGANISATION AND GOVERNANCE

- 👍 **Expand emergency care services to rural areas through targeted training (e.g., WHO Basic Emergency Care Course, AO Foundation courses, trauma team training) and by ensuring the**

availability of essential resources (i.e., low-cost, high-value-added resources) in existing facilities.

- 👍 **Create a steering committee to assist in the translation of the annual road safety status report into action priorities for improving emergency care.**
 - Establish an office or lead agency within the Ministry of Health or a steering committee with a liaison within the Ministry of Health for emergency care to advocate for, coordinate and develop emergency care services.
 - Collaborate with surgical care stakeholders (e.g., Ghana College of Physicians and Surgeons, academic institutions, health policy analysts) to integrate emergency and essential surgical care into the national health plan.

FINANCING

- 👍 **Leverage funding for disease-specific or tangential initiatives that intersect with the emergency care system to support emergency care training and capacity development (e.g., Ebola, HIV/AIDS, TB, maternal health, childhood diarrhea, emergency and disaster preparedness).**
- 👍 **Include prehospital and emergency medicine specialists in decisions to source and procure emergency care equipment and supplies, which might save money by avoiding purchase of unnecessary or costly resources that do not add substantial value to emergency care; consider using the WHO Essential Resources for Emergency Care to inform procurement decision-making.**
 - Explore other ways to generate revenue dedicated to emergency care from industries whose products or workplaces contribute to the burden of emergency conditions using the corporate social responsibility framework to supplement revenue gained from vehicle sales and registration (e.g., tax alcohol, tobacco, and firearm products; engage the telecom, oil and gas, and mining industries).
 - Cost emergency care services at each level of care, and map actual costs of care delivery to existing National Health Insurance Scheme (NHIS) codes used for reimbursement to identify gaps and disproportionately low reimbursement rates; propose a new tariff structure for emergency care services that would be commiserate with the cost of delivering emergency care, and be proportionate when compared to other healthcare services.
 - Advocate for the prioritization of NHIA reimbursements for emergency care service delivery so that patients with emergency conditions are able to receive free and timely care; at a minimum, emergency care should be free within the first 48 hours of acute illness or injury.

EMERGENCY CARE DATA

- 👍 **Develop a working group to propose and pilot better strategies for emergency care data collection, management, integration, linkage and reporting comprised of key stakeholders and experts (e.g., NAS; GHS; NRSC; MOH Policy, Planning, Monitoring and Evaluation Office; health**

information management officers; emergency medicine specialists; traumatologists; rehabilitation specialists); use the WHO Minimum Dataset for Emergency Conditions and WHO Minimum Dataset for Injury as guides for the development facility-based data collection systems.

- 👍 **Pilot collection and reporting of sentinel emergency conditions using the HAMS and DHIS-2 platforms to guide better understanding of the burden of emergency conditions on the healthcare system, as well as resource allocation for emergency care services.**
- 👍 **Create standardised intake forms for use in emergency units countrywide to facilitate better care, more efficient documentation, and data reporting.**
- 👍 **Engage the office of the non-communicable diseases (NCD) to gain support for systematic data collection and reporting of NCD-related emergencies (e.g., asthma exacerbations, heart attacks, strokes, complications of diabetes), which can be used for system planning and advocacy.**
- Integrate the WHO Minimum Dataset for Injury into facility-based health information systems as they are being developed.

QUALITY IMPROVEMENT

- 👍 **Teach emergency care quality improvement fundamentals to providers at each level of care.**
- 👍 **Select specific emergency conditions (e.g., severe injury, paediatric diarrhea, suspected heart attack) to serve as sentinel conditions whose outcomes can be tracked to evaluate emergency care functions as outlined by the WHO Emergency Care Systems Framework.**
- Incorporate emergency and trauma care quality improvement initiatives into existing system-wide quality improvement structures, such as those for maternal death audits.
- Create a structure that allows reporting of problems identified, corrective actions taken, and consequent effect of corrective actions on the clinical outcomes of patients with emergency conditions.

SCENE CARE

- 👍 **Advocate for 1-1-2 being toll-free on all carriers in function and accessible across the country 24 hours per day.**
- 👍 **Restart real-time medical direction of prehospital care providers by utilising the new cadre of emergency medicine specialists; propose volunteer medical direction posts in each region.**
- 👍 **Re-introduce basic emergency care training into the NFS curriculum to extend population-level access to prehospital care services in areas without NAS coverage, and to improve emergency and disaster preparedness.**
- Support the NAS by assisting in community-based initiatives to teach 1-1-2 and its use to the population when NAS is ready to expand services.
- Work with the NAS to pilot a medical priority dispatch system that offers bystander instructions when needed, which can be either electronically based or a card system.

- Ensure that there is a single designated telephone or radio at each facility that functions and with a staff member assigned to answer incoming calls 24 hours per day; prehospital providers should have access to the telephone numbers or radio frequencies of each facility so that they can communicate with the receiving facility prior to arrival.
- Develop destination triage protocols for all prehospital care providers so that patients can be cared for in the most safe and timely manner possible by facilities with the necessary capacity; destination triage protocols for injury can be piloted along roadways with a high incidence of road traffic crashes, and be monitored and evaluated in coordination with the NRSC.
- Incorporate GRCS-trained laypersons into the formal prehospital care system to expand population-level access to prehospital care services.

TRANSPORT AND TRANSFER

- Actively support passage of the National Ambulance Service Bill, which will provide central coordination of prehospital care and a regulatory framework for all ambulance services.
- 👍 **Develop and disseminate transfer criteria for key emergency conditions to improve timely access to necessary emergency and surgical care.**
- Introduce and enforce a mandate for all providers to communicate with a potential receiving facility prior to transfer to: i) determine if transfer is appropriate and feasible; ii) obtain clinical decision-making support, if needed; and iii) allow the receiving facility prepare for the patient and his/her immediate needs.
- 👍 **Build training regarding safe transfer and transfer criteria into the curriculum of house officers before they are posted to regional or district hospitals.**
- Develop a formal feedback system for referrals so that poor care or transfer decision-making can be improved, and good care or decision-making can be reinforced.
- Create a map of facilities with emergency condition-specific care capacity (e.g., fracture care) to inform transfer decision-making and alleviate the burden of inappropriate transfers on teaching hospitals in cases where there is a regional or district hospital with the necessary capacity within similar geographic range.

FACILITY-BASED CARE

- 👍 **Establish facility designation criteria and an accreditation system for specific emergency and trauma care services.**
- 👍 **Train district hospital providers in triage components to promote patients being seen in order of acuity.**
- 👍 **Implement team-based and inter-professional training for emergency care to improve care delivery and strengthen communication skills and relationships among nurses and doctors; ideally, this would begin at the pre-service level (i.e., during training).**

- 👍 **Adapt externally validated protocols for the care of emergency conditions to local contexts, and implement the protocols at hospitals countrywide; compliance with protocols should be linked to facility designation and accreditation schemes.**
- 👍 **Explore the promotion of 'step-down transfers' (i.e., from teaching hospitals to district hospitals near the patient's home for convalescence) and the reimbursement implications of doing so with the NHIA in an effort to keep large hospital emergency units below capacity and able to accept transfers.**
- 👍 **Model the cost and revenue differences associated with the following two scenarios to support emergency units efforts to remain below capacity and able to accept transfers: i) the current situation, where inpatients are often required to stay until the bill is paid, which leads to backlog in the emergency unit and operating beyond capacity; and ii) a potential situation, where inpatients are allowed to be discharged without paying the bill in its entirety, which opens beds for patients with emergency conditions who need to be admitted after stabilisation and allows new emergencies to be seen in a timely manner.**
- Establish routine screening for sentinel conditions prior to registration at all acute care facilities with links to public health officials for case definitions and reporting.
- Review, with stakeholders (e.g., Ghana College of Physicians and Surgeons, relevant universities), the existing curriculae for orthopaedic surgery and general surgery training programmes in Ghana and trauma surgery programmes in other countries to identify gaps related to the care of the injured; work with stakeholders to redress the gaps and update the curriculae of surgical training programmes to ensure that injured patients in need of trauma surgical care can receive it when needed.

REHABILITATION FOR EMERGENCY CONDITIONS

- 👍 **Highlight effectiveness of existing rehabilitation services to generate more support for rehabilitation care; this could become a compendium of success stories and lessons learned from rehabilitation services across the country (e.g., Prosthetics and Orthotics Training College; Komfo Anokye Teaching Hospital Stroke Centre; Korle Bu Physiotherapy Department; district-level rehabilitation centers, such as those in Akim Oda or Techiman).**
- 👍 **Communicate the value of early physiotherapy and both inpatient and outpatient rehabilitation services to healthcare providers who take care of patients who have had an emergency condition (e.g., fracture, traumatic brain injury, burn, heart attack, stroke).**
- Develop and pilot pictorial cards that demonstrate basic physiotherapy maneuvers for specific conditions for use by appropriately selected patients and their families/caregivers after discharge.
- Incorporate medical social work into the GHS to improve linkages for people with disability to rehabilitation, workplace support programmes and social protection agencies and advocates.
- Engage the private sector to collaborate with GHS, and consider subsidising rehabilitation services with the revenue from fitness consultations and memberships at rehabilitation facilities.

EMERGENCY AND DISASTER PREPAREDNESS

- 👍 **Include emergency nurses, emergency medicine specialists, anaesthetists and surgical care providers in discussions regarding national, regional and local emergency response planning.**
- 👍 **Develop a resource-appropriate template and checklist for healthcare facilities at all levels of care to use when developing local emergency response plans.**
- 👍 **Incorporate the presence and staff knowledge of an emergency response plan into facility designation and accreditation schemes.**
- Consider regional emergency response plans to be able to adequately respond to disasters that are beyond the scope of a facility emergency response plan, but that do not require the mobilisation of national resources.

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LIST OF ABBREVIATIONS

CHAG – Christian Health Association of Ghana
CHPS – Community-based Health Planning and Services
DHIMS – District Health Information Management System
DHIS-2 – District Health Information System 2
ECSAT – Emergency Care System Assessment Tool
GHS – Ghana Health Service
GRCS – Ghana Red Cross Society
HAMS – Hospital Administration and Management System
HIV/AIDS – Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome
KATH – Komfo Anokye Teaching Hospital
KNUST – Kwame Nkrumah University of Science and Technology
LMICs – Low- and middle-income countries
MERS – Middle East Respiratory Syndrome
MOH – Ministry of Health
NADMO – National Disaster Management Organisation
NAS – National Ambulance Service
NCDs – Non-communicable diseases
NFS – National Fire Service
NHIA – National Health Insurance Authority
NHIS – National Health Insurance Scheme
NPS – National Police Service
NRSC – National Road Safety Commission
SARS – Severe Acute Respiratory Distress Syndrome
TB – Tuberculosis
WHO – World Health Organization

1 . INTRODUCTION

Emergency care systems address a wide-range of common medical, surgical, and obstetric conditions, including injury, complications of pregnancy, exacerbations of non-communicable diseases (e.g. asthma, heart attacks, strokes), and acute infections (e.g. sepsis, malaria).¹ The emergency care system is often patients' first point of contact, particularly in areas where significant barriers to care exist.¹³ With sound planning and organisation, emergency care systems have the potential to address nearly half of deaths and more than a third of disability annually in low- and middle-income countries (LMICs).^{2,3}

Despite the potential benefit of organised emergency care systems, many countries have not fostered the political will required to develop such systems.¹⁴ Resultantly, most emergency care systems are ad hoc and disorganized, underfunded, lack legislation and governance, and are plagued by insufficient human and physical resources (e.g., equipment and supplies).¹⁵ Thus, these systems are not able to provide timely and effective care for the majority of the population, which leads to substantial preventable death and disability.¹⁶

2 . EMERGENCY CARE IN GHANA

There have been modest improvements in emergency care capacity over the last decade in Ghana. Nonetheless, a number of recent population-level access and prehospital- and facility-based assessments have demonstrated: poor access to emergency care for the majority of the population;^{4,5} critical deficiencies in essential resources;^{4,6-8} insufficient training;⁸⁻¹¹ and lack of organisation.¹²

The findings from the aforementioned assessments contribute to the higher estimated injury-related mortality rate in Ghana (51 injury deaths per 100,000 population) than in a number of other sub-Saharan African countries: Madagascar – 34 injury deaths per 100,000 population; Liberia – 40 per 100,000; Zambia and Kenya – 41 per 100,000; and Senegal – 48 per 100,000.¹⁷ For reference, the mortality rate from all maternal disorders combined in Ghana (e.g., obstructed labor, peripartum haemorrhage, eclampsia) is 9 deaths per 100,000 population; tuberculosis – 14 per 100,000; and HIV/AIDS – 54 per 100,000. The overall mortality rate for conditions that could be addressed by emergency care (i.e., not only injuries) is not available; however, it is likely substantially higher than that for injury alone.^{18,19}

3 . EMERGENCY CARE SYSTEM ASSESSMENT AND WORKING GROUP

Given the potential to reduce death and disability from emergency conditions in Ghana through improvements in the emergency care system, the Ghana Health Service (GHS) teamed up with Kwame Nkrumah University of Science and Technology (KNUST) and World Health Organization's (WHO) Emergency, Trauma and Acute Care programme to conduct a system-level assessment of emergency care and organize a working group composed predominantly of local experts in the emergency care system.

GHS approached stakeholders from the Ministry of Health, National Ambulance Service (NAS), National Disaster Management Organisation (NADMO), National Fire Service (NFS), National Police Service (NPS), Ghana Red Cross Society (RCS), National Road Safety Commission (NRSC), Ghana College of Nurses and Midwives, Ghana College of Physicians and Surgeons, Christian Health Association of Ghana (CHAG), AO Foundation, and each level of community and facility-based care [i.e., community health workers, Community-based Health Planning and Services (CHPS), primary health care centres (PHC), district hospitals, regional hospitals, teaching hospitals], as well as both local and international prehospital care and emergency medicine specialists and traumatologists.

Stakeholders were asked to complete the WHO Emergency Care System Assessment Tool (ECSAT). The WHO ECSAT is a survey that was developed to identify strengths and weaknesses of the following components of a national emergency care system: system organisation and governance; financing; emergency care data; quality improvement; scene care; transport and transfer; facility-based care; rehabilitation for emergency conditions; and emergency and disaster preparedness. The findings from the assessment can be used to inform action priorities for strengthening the emergency care system.

Twenty-five of the 34 stakeholders approached completed the WHO ECSAT. The surveys were compiled and the results analysed (Appendix 1). On March 21st and 22nd of 2016, Ghana Health Service hosted stakeholders at a working group meeting that aimed to: i) review the WHO ECSAT results; ii) identify gaps in the emergency care system; iii) develop consensus-based action priorities, particularly those that require minimal additional resources; and iii) highlight existing resources and potential implementing partners. The following sections describe the results from the WHO ECSAT and output from the working group. The action priorities for each component of the emergency care system proposed by the working group are listed by WHO ECSAT section below. Action priorities in bold represent those that are high-yield, feasible in the near-term and/or would require only minimal added resources.

4. RESULTS FROM THE WHO ECSAT AND OUTPUT FROM THE WORKING GROUP

4.1. SYSTEM ORGANISATION AND GOVERNANCE

There is not a designated office or lead agency within the government responsible for emergency care and coordination of stakeholders; nor is there a legal mandate to ensure or enforce compliance. Instead, emergency care is managed by multiple stakeholders, including the NAS, Institutional Care Division of the GHS, and NADMO. While prehospital and facility-based emergency care are integrated into the national health plan, emergency surgical services are not explicitly included. In part due to the lack of central coordination and advocacy, stakeholders reported that there is some emergency care in urban settings, though not adequate to population needs, and there is no or minimal emergency care availability in rural settings.

There is an annual road safety status report that is prepared by the NRSC from multiple sources (e.g., NPS, Building and Roads Research Institute, mortuary records) and is externally verified; however, the report could be better used for purposes of quality improvement and resource allocation. There is not a status report for either injury or emergency care.

ACTION PRIORITIES

- 👍 **Expand emergency care services to rural areas through targeted training (e.g., WHO Basic Emergency Care Course, AO Foundation courses, trauma team training) and by ensuring the availability of essential resources (i.e., low-cost, high-value-added resources) in existing facilities.**
- 👍 **Create a steering committee to assist in the translation of the annual road safety status report into action priorities for improving emergency care.**
 - Collaborate with surgical care stakeholders (e.g., Ghana College of Physicians and Surgeons, academic institutions, health policy analysts) to integrate emergency and essential surgical care into the national health plan.
 - Establish an office or lead agency within the Ministry of Health for emergency care to advocate for, coordinate and develop emergency care services.

4.2. FINANCING

Although there is a funding scheme for emergency care linked to both vehicle registration and taxation, the resulting revenue is not made available for emergency care system development. Dedicated funding for emergency care services, including prehospital and facility-based care, is critically deficient.

There is legislation designed to ensure that no payment is required prior to emergency care; some groups receive entirely free care, and others pay afterwards. However, NAS funding is inadequate, and National Health Insurance Authority (NHIA) total timely reimbursement rates to hospitals are low, which has caused many emergency care services to revert to cash and carry; payment is often required before emergency care is rendered.^{8,20-22} The current NHIA tariff structure contributes to the lack of appropriate reimbursements for emergency care; the structure does not reflect the actual costs of emergency care delivery, and is disproportionately lower when compared to other healthcare services (e.g., maternal care).

ACTION PRIORITIES

- Leverage funding for disease-specific or tangential initiatives that intersect with the emergency care system to support emergency care training and capacity development (e.g., Ebola, HIV/AIDS, TB, maternal health, childhood diarrhea, emergency and disaster preparedness).**
- Include prehospital and emergency medicine specialists in decisions to source and procure emergency care equipment and supplies, which might save money by avoiding purchase of unnecessary or costly resources that do not add substantial value to emergency care; consider using the WHO Essential Resources for Emergency Care to inform procurement decision-making.**
- Cost emergency care services at each level of care, and map actual costs of care delivery to existing National Health Insurance Scheme (NHIS) codes used for reimbursement to identify gaps and disproportionately low reimbursement rates; propose a new tariff structure for emergency care services that would be commiserate with the cost of delivering emergency care, and be proportionate when compared to other healthcare services.
- Advocate for the prioritization of NHIA reimbursements for emergency care service delivery so that patients with emergency conditions are able to receive free and timely care; at a minimum, emergency care should be free within the first 48 hours of acute illness or injury.
- Explore other ways to generate revenue dedicated to emergency care from industries whose products or workplaces contribute to the burden of emergency conditions using the corporate social responsibility framework to supplement revenue gained from vehicle sales and registration (e.g., tax alcohol, tobacco, and firearm products; engage the telecom, oil and gas, and mining industries).

4.3. EMERGENCY CARE DATA

Data from the following sources are regularly gathered and used for emergency care system planning: prehospital, police, and health facility records. Data from other sources are either less regularly gathered or not

used for system planning: mortuary records; death certificates; community-based surveys; and insurance company records. Despite data being collected from multiple sources, there is no linkage between sources to better inform system planning and facilitate monitoring and evaluation.

From these sources, only basic data are collected (e.g., location of illness or injury, age, sex, chief complaint). However, other data that would be useful for system planning are not regularly collected (e.g., community response; mode of transportation to facility; prehospital care delivered; clinical severity score; process metrics, such as timing of interventions or disposition; clinical outcome, such as morbidity or mortality).

ACTION PRIORITIES

- 👍 **Develop a working group to propose and pilot better strategies for emergency care data collection, management, integration, linkage and reporting comprised of key stakeholders and experts (e.g., NAS; GHS; NRSC; MOH Policy, Planning, Monitoring and Evaluation Office; health information management officers; emergency medicine specialists; traumatologists; rehabilitation specialists); use the WHO Minimum Dataset for Emergency Conditions and WHO Minimum Dataset for Injury as guides for the development facility-based data collection systems.**
- 👍 **Pilot collection and reporting of sentinel emergency conditions using the HAMS and DHIS-2 platforms to guide better understanding of the burden of emergency conditions on the healthcare system, as well as resource allocation for emergency care services.**
- 👍 **Create standardised data collection forms for use in emergency units countrywide to facilitate better care, more efficient documentation, and data reporting.**
- 👍 **Engage the office of the non-communicable diseases (NCD) to gain support for systematic data collection and reporting of NCD-related emergencies (e.g., asthma exacerbations, heart attacks, strokes, complications of diabetes), which can be used for system planning and advocacy.**
- Integrate the WHO Minimum Dataset for Injury into facility-based health information systems as they are being developed.

4.4.4. QUALITY IMPROVEMENT

Although clinical data are systematically recorded in a standardised manner by the NAS, other prehospital care and interfacility transfer services do not collect data in a standardised manner. Medical records at individual facilities are predominantly stored in paper charts without a method for linking one encounter to another. Further, clinical data are not collected in a standardised manner across facilities to allow benchmarking. Data are rarely entered into a database that would facilitate regular clinical audit.

Although quality improvement programmes for emergency care exist in some facilities, they infrequently result in corrective actions that are monitored, evaluated and verified. However, maternal care initiatives have been able to organise both facility-based and system-wide quality improvement initiatives including preventable death panel reviews and regular clinical audits. Outside of maternal care initiatives, there are no system-wide quality improvement programmes. In facilities that do have quality improvement programmes, they are typically limited to morbidity and mortality conferences. Preventable death panel reviews for emergency conditions have not been widely adopted outside of teaching hospitals;¹⁶ routine clinical audit using performance metrics and outcome data is not employed, even at tertiary hospitals.

The lack of quality improvement programmes means that corrective strategies (e.g., implementation of guidelines and protocols; targeted education; improvement of communication strategies, infrastructure, or equipment) are rarely utilised to improve clinical outcomes.

ACTION PRIORITIES

- 👍 **Teach emergency care quality improvement fundamentals to providers at each level of care.**
- 👍 **Select specific emergency conditions (e.g., severe injury, paediatric diarrhea, asthma) to serve as sentinel conditions whose outcomes can be tracked to evaluate emergency care functions as outlined by the WHO Emergency Care Systems Framework (Appendix 2).**
 - Incorporate emergency and trauma care quality improvement initiatives into existing system-wide quality improvement structures, such as those for maternal death audits.
 - Create a structure that allows reporting of problems identified, corrective actions taken, and consequent effect of corrective actions on the clinical outcomes of patients with emergency conditions.

4.5. SCENE CARE

Although there is a single emergency access telephone number (1-1-2) and legislation that requires fixed and mobile telephone carriers to provide free connection to the emergency access telephone number, connection is not always free and there are substantial geographic coverage gaps. Further, it is estimated that less than 25% of the population knows and can properly use the emergency access number by memory. Note that the NAS has intentionally controlled promotion of the emergency access telephone number to avoid not being able to respond promptly given existing resources, which might result in a loss of confidence in NAS services.

There is an organised national prehospital care system with certified prehospital care providers (i.e., NAS) and a number of private ambulance services; however, the majority of the population in both urban and rural areas does not have access to prehospital care services due to inadequate numbers of ambulances, staff and stations. If the emergency access telephone number is called, callers are connected to the appropriate service (e.g., NAS, NPS, NFS). If the call pertains to a condition that requires emergency care, providers can be dispatched to the scene or facility. There are no nationally agreed upon response times used by all ambulance services for responding to the highest priority calls.

Currently, dispatch services do not routinely provide standardised basic clinical advice to bystanders. Once prehospital care providers arrive, their care is often governed by protocols, particularly if they are NAS providers; however, they lack real-time medical direction, a backup advisory mechanism to provide extra clinical support, and a communication system to do so, if needed. There are no destination triage protocols for prehospital care providers; decisions on where to transfer a patient with a given emergency condition are made based on provider and/or patient preference.

Information about the patient, care provided during transport, and immediate clinical care needs is rarely given to the receiving facility prior to arrival. There is no system-wide automated tracking of caller location via telephone or other methods; however, there is a pilot program evaluating this technology in Greater Accra Region. The NAS performs regular audit of prehospital care data for quality assurance and improvement purposes.

To augment existing prehospital care capacity, GRCS and St. Johns Ambulance Service train laypersons in first aid using validated courses, provide trainees with basic emergency care provider kits, and use a credentialing system. GRCS has trained more than 40,000 laypersons; however, layperson first responders are not widely available when needed, and they are not integrated into the formal prehospital care system administrative or credentialing structures. Recently, GRCS began piloting a tricycle ambulance programme in Upper East Region to extend prehospital care service to those currently without access to the NAS when needed. Despite these significant efforts, there is not a centrally regulated layperson first responder training programme with overall coordination or quality control mechanisms.

Strictly speaking, there is not a 'Good Samaritan' law in Ghana to protect laypersons who provide first aid; however, according to Common law and legal precedent, if a layperson offers help within their means, they could seek protection from harm caused to a victim.

Prior to formation of the NAS, NFS training included basic emergency care that was supported by the GRCS. As the NAS developed, the NFS has abridged first aid training and is now unable to act in the capacity of a first responder, even during disasters.

ACTION PRIORITIES

- 👍 **Advocate for 1-1-2 being toll-free on all carriers in function and accessible across the country 24 hours per day.**
- 👍 **Restart real-time medical direction of prehospital care providers by utilising the new cadre of emergency medicine specialists; propose volunteer medical direction posts in each region.**
- 👍 **Re-introduce basic emergency care training into the NFS curriculum to extend population-level access to prehospital care services in areas without NAS coverage, and to improve emergency and disaster preparedness.**
 - Support the NAS by assisting in community-based initiatives to teach 1-1-2 and its use to the population when NAS is ready to expand services.
 - Work with the NAS to pilot a medical priority dispatch system that offers bystander instructions when needed, which can be either electronically based or a card system.
 - Ensure that there is a single designated telephone or radio at each facility that functions and with a staff member assigned to answer incoming calls 24 hours per day; prehospital providers should have access to the telephone numbers or radio frequencies of each facility so that they can communicate with the receiving facility prior to arrival.
 - Develop destination triage protocols for all prehospital care providers so that patients can be cared for in the most safe and timely manner possible by facilities with the necessary capacity; destination triage protocols for injury can be piloted along roadways with a high incidence of road traffic crashes, and be monitored and evaluated in coordination with the NRSC.
 - Incorporate GRCS-trained laypersons into the formal prehospital care system to expand population-level access to prehospital care services.

4.6. TRANSPORT AND TRANSFER

Although there is reasonable knowledge about the capabilities of teaching hospitals and some other facilities, there is not a formal facility designation and accreditation system for specific emergency conditions (e.g., trauma, cardiac, or stroke centres) to guide transfer decision-making.

The National Ambulance Service Bill is yet to be passed in Parliament. The Bill has a number of important components that would strengthen the emergency care system and provisions that mandate NAS to coordinate all ambulance services, including governing the use of ambulances (e.g., licensing, vehicle upkeep, compliance

with equipment and supply norms and standards, and compliance with national traffic laws), communication, and prehospital care provider handovers to facilities.

Although there is a policy that requires both a driver and a care provider for ambulance transport, current emergency care workforce limitations restrict the compliance of this policy to NAS services, which predominately are inter-facility transfers.

There are not system-wide protocols for inter-facility patient transfers (i.e., there are no transfer criteria for individual regions or the country). Patients are transferred between healthcare facilities based on individual decisions, such as patient or provider preference, even for emergency conditions that require specialised care (e.g., severe burn, heart attack, serious injury). Transfers between facilities require a referral note from the transferring facility to the receiving facility; however, these are brought with the patient and often lack critical information for the timely and effective management of the patient.²³ Generally, communication between facilities regarding patient transfer happens in an uncoordinated manner based on individual decisions, if at all.

ACTION PRIORITIES

- 👍 **Develop and disseminate transfer criteria for key emergency conditions to improve timely access to necessary emergency and surgical care.**
- 👍 **Build training regarding safe transfer and transfer criteria into the curriculum of house officers before they are posted to regional or district hospitals.**
- 👍 **Explore the promotion of 'step-down transfers' (i.e., from teaching hospitals to district hospitals near the patient's home for convalescence) and the reimbursement implications of doing so with the NHIA in an effort to keep large hospital emergency units below capacity and able to accept transfers.**
- 👍 **Model the cost and revenue differences associated with the following two scenarios to support emergency units efforts to remain below capacity and able to accept transfers: i) the current situation, where inpatients are often required to stay until the bill is paid, which leads to backlog in the emergency unit and operating beyond capacity; and ii) a potential situation, where inpatients are allowed to be discharged without paying the bill in its entirety, which opens beds for patients with emergency conditions who need to be admitted after stabilisation and allows new emergencies to be seen in a timely manner.**
- Actively support passage of the National Ambulance Service Bill, which will provide central coordination of prehospital care and a regulatory framework for all ambulance services.

- Introduce and enforce a mandate for all providers to communicate with a potential receiving facility prior to transfer to: i) determine if transfer is appropriate and feasible; ii) obtain clinical decision-making support, if needed; and iii) allow the receiving facility prepare for the patient and his/her immediate needs.
- Develop a formal feedback system for referrals so that poor care or transfer decision-making can be improved, and good care or decision-making can be reinforced.
- Create a map of facilities with emergency condition-specific care capacity (e.g., fracture care) to inform transfer decision-making and alleviate the burden of inappropriate transfers on teaching hospitals in cases where there is a regional or district hospital with the necessary capacity within similar geographic range.

4.7. FACILITY-BASED CARE

There is a policy designed to ensure that every acute care facility in the country has an area designated for emergency care. At district hospitals, this area is typically present, though not necessarily staffed by a provider trained in emergency care or a provider that is assigned solely to the emergency unit. Further, patients are often not triaged, and are generally seen in order of arrival. At teaching hospitals, emergency units are typically staffed 24 hours per day, usually by a provider trained in emergency care who is assigned to the emergency unit; teaching hospitals have standardised triage protocols, and are seen in order of acuity. It is estimated that less than 25% of the population has 24-hour access to facility-based emergency care in a dedicated unit with independent, non-rotating, trained emergency care providers regardless of urban or rural residence.

Facility-based assessments of emergency care capacity have demonstrated marked deficiencies, even for low-cost resources (e.g., basic airway supplies, chest tubes, plaster of Paris, essential medications).^{6,8,16} While resource deficiencies are more commonly encountered at district hospitals, care at larger hospitals (i.e., regional and teaching hospitals) is also limited by a lack of essential resources.²⁴

Despite a policy mandating triage of acutely ill and injured patients prior to registration, triage for emergency conditions is rarely performed outside of teaching and some regional hospitals. Specifically, district hospitals typically lack formal triage protocols and personnel dedicated to triage at all times. In facilities that perform triage routinely, there is a lack of time targets for certain triage destinations (i.e., acuity levels) and no compliance tracking for triage time targets.

There are two accredited emergency medicine specialist training programmes in Ghana, in addition to specialist training programmes in anaesthesia and critical care. Although there are orthopaedic specialist training programmes, these do not teach the breadth of general trauma surgery, which includes resuscitation and surgical care of injuries to the neck, chest, pelvis and abdomen. Thus, there is no comprehensive training

program for trauma surgery. Recently, the Nursing and Midwifery Council of Ghana has accredited post-graduate degree courses for emergency nursing.

Providers who regularly care for emergency conditions are supposed to have undergone dedicated training in emergency care according to a GHS policy; however, non-doctors rarely receive dedicated emergency care training. When emergency care training is provided to doctors, it typically only entails care for injuries and does not cover the care of other emergency conditions.

Screening at the time of registration in the emergency unit is under-utilised countrywide. Some facilities screen each patient for diabetes, HIV and/or TB. However, outside of times of outbreak, most patients do not get screened for other conditions of public health importance, such as domestic violence and child maltreatment, other forms of violence, or substance abuse. As demonstrated during the recent Ebola epidemic, there is a mechanism for screening patients at time of registration at an emergency unit for highly contagious conditions (e.g., Ebola, SARS, MERS) with links to public health officials for case definitions and reporting.

Some emergency units use protocols to govern the management of key emergency conditions, but these are not consistently used and are often not externally validated, particularly those outside of emergency obstetric care.

It is estimated that less than 25% of the population have access to essential surgical care in a staffed operating theatre within two hours of acute surgical illness or injury. Similarly, due to prohibitively expensive user-fees, lack of resources and a shortage of trained providers, orthopaedic and specialist surgical care services (e.g., neurosurgery, advanced burn care) are not available for the majority of the population when needed.

There are no nationally agreed upon targets for emergency unit length of stay. Although there is a policy regarding the information that ought to be communicated to patients about their disposition or discharge, there are no protocols to guide this interaction. Further, for patients who are discharged, there are rarely formal linkages between the emergency unit and primary/longitudinal care or other outpatient services.

ACTION PRIORITIES

- 👍 **Establish facility designation criteria and an accreditation system for specific emergency and trauma care services.**
- 👍 **Implement team-based and inter-professional training for emergency care to improve care delivery and strengthen communication skills and relationships among nurses and doctors; ideally, this would begin at the pre-service level (i.e., during training).**

- 👍 **Adapt externally validated protocols for the care of emergency conditions to local contexts, and implement the protocols at hospitals countrywide; compliance with protocols should be linked to facility designation and accreditation schemes.**
- 👍 **Review, with stakeholders (e.g., Ghana College of Physicians and Surgeons, relevant universities), the existing curriculae for orthopaedic surgery and general surgery training programmes in Ghana and trauma surgery programmes in other countries to identify gaps related to the care of the injured; work with stakeholders to redress the gaps and update the curriculae of surgical training programmes to ensure that injured patients in need of trauma surgical care can receive it when needed.**
- Establish routine screening for sentinel conditions prior to registration at all acute care facilities with links to public health officials for case definitions and reporting.
- Train district hospital providers in triage components to promote patients being seen in order of acuity.

4.8. REHABILITATION

The Ministry of Gender, Children and Social Protection and the Ministry of Health are both charged with ensuring adequate rehabilitation services are available when needed. Further, the National Council on Persons with Disability serves as a coordinating body within the government. While rehabilitation services are included in the working plans of multiple agencies (e.g., GHS), there is not a national action plan for rehabilitation. The lack of an action plan is due, in part, to a lack of understanding about the epidemiology of rehabilitation needs, the burden of disability and a mechanism for monitoring and documenting existing rehabilitation services. As such, rehabilitation services are underfunded and not integrated in the health service provision.

Although basic rehabilitation services (e.g., basic physiotherapy) are available at some district hospitals, they are often not included as part of care for emergency conditions after the acute period. Larger hospitals provide more rehabilitation services, but the services are still not often available for patients in need due to lack of capacity or cost, or poor linkage between acute care and rehabilitation services. Most hospitals do not have rehabilitation wards and are not linked with a rehabilitation facility. Although there are a number of rehabilitation facilities in Ghana, they are not well distributed to ensure equitable geographic access, and are under-utilised. Although there have been community- and home-based rehabilitation initiatives, they are not well supported and are not available for the vast majority of the population despite their cost-effectiveness.

There are training centres for rehabilitation professionals (e.g., University of Legon, Kwame Nkrumah University of Science and Technology, Orthopedic Training Centre); however, graduates do not get posted within the public sector often, which leads them to seek employment in the private sector. Similarly, certificate programs exist,

such as those in Duayaw Nkwanta and Suhum, but graduates do not get adequate financial or professional support to develop rehabilitation services in areas where they currently do not exist.

The Ministry of Gender, Children and Social Protection have policies and programmes that support people with disability, both physical and psychological, returning to work; however, the policies are not widely adhered to and there are significant barriers to enforcement. Similarly, the number of such programmes is few and is not able to support the majority of people with disabilities attempting to rejoin the workforce. Social services provided by trained social workers at healthcare facilities or district health service are not available to support people with disability as they attempt to reintegrate into their communities and identify potentially useful resources.

ACTION PRIORITIES

- 👍 **Highlight effectiveness of existing rehabilitation services to generate more support for rehabilitation care; this could become a compendium of success stories and lessons learned from rehabilitation services across the country (e.g., Prosthetics and Orthotics Training College; Komfo Anokye Teaching Hospital Stroke Centre; Korle Bu Physiotherapy Department; district-level rehabilitation centers, such as those in Akim Oda or Techiman).**
- 👍 **Communicate the value of early physiotherapy and both inpatient and outpatient rehabilitation services to healthcare providers who take care of patients who have had an emergency condition (e.g., fracture, traumatic brain injury, burn, heart attack).**
 - Develop and pilot pictorial cards that demonstrate basic physiotherapy maneuvers for specific conditions for use by appropriately selected patients and their families/caregivers after discharge.
 - Incorporate medical social work into the GHS to improve linkages for people with disability to rehabilitation, workplace support programmes and social protection agencies and advocates.
 - Engage the private sector to collaborate with GHS, and consider subsidising rehabilitation services with the revenue from fitness consultations and memberships at rehabilitation facilities.

4.9. EMERGENCY AND DISASTER PREPAREDNESS

National emergency and disaster preparedness is coordinated by the National Disaster Management Organisation; region-specific plans do not exist. There is an emergency response plan involving multiple necessary agencies; however, there is no requirement for periodic evaluation via mock simulation drills. Further, there are no regular assessments of the ability of the emergency care system to mobilize additional resources

(e.g., human and physical resources, alternate communication strategies, alternate transport mechanisms for personnel to patients) to respond to disasters, outbreaks and other large-scale emergencies.

All facilities under the GHS are to have a local emergency response plan in the case of mass casualty incidents or an emergency in, or immediately around, the facility. However, most facilities do not have such a plan that outlines incident command structure, initiating backup power, water and communication infrastructure, mobilising additional resources, establishing additional clinical and morgue space, using modified triage protocols, etc. Emergency response plans do not include community-level or sub-district stakeholders, such as community health workers, CHPS, PHCs, or GPRTU.

ACTION PRIORITIES

- 👍 **Include emergency nurses, emergency medicine specialists, anaesthetists and surgical care providers in discussions regarding national, regional and local emergency response planning.**
- 👍 **Develop a resource-appropriate template and checklist for healthcare facilities at all levels of care to use when developing local emergency response plans.**
- 👍 **Incorporate the presence and staff knowledge of an emergency response plan into facility designation and accreditation schemes.**
- Consider regional emergency response plans to be able to adequately respond to disasters that are beyond the scope of a facility emergency response plan, but that do not require the mobilisation of national resources.

5. NEXT STEPS

The WHO ECSAT provided a broad assessment of the emergency care system. From the assessment results, stakeholders were able to identify critical gaps in the emergency care system. To address the gaps identified, a set of action priorities for each component of the system have been proposed and are listed above.

Addressing some of these action priorities will not require significant added resources, and can be implemented by partners already working within the emergency care system if engaged and supported by the government; there are a number of existing partners that could perform much of the technical assistance, development, piloting and implementation of the action priorities. Other action priorities will require added resources, and may benefit from mobilising additional implementing partners.

Formation of a lead agency for emergency care within the Ministry of Health, or at a minimum a steering committee comprised of key stakeholders with a clear liaison mechanism to the Ministry of Health, would greatly facilitate the coordination of the existing emergency care system actors (e.g., NAS, GHS, CHAG, CHPS, emergency care departments at teaching hospitals), as well as the activities that may stem from the above action priorities. Further, such an agency or steering committee could ensure that there are not parallel or redundant initiatives, and ensure that appropriate monitoring, evaluation and reporting strategies are included in programmes designed to address action priorities. In addition to coordination of the emergency care system components and their development, a lead agency or steering committee should be mandated to regularly report progress on action priorities, perform serial system assessments and identify and act on newly identified pertinent action priorities.

While the exact and incremental benefits of each of the action priorities are unknown, the action priorities above represent reasonable next steps in the development of the national emergency care system. Each of the action priorities above has the potential to significantly improve the emergency care system and the outcomes of acutely ill and injured people countrywide.

REFERENCES

1. GBD_Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015; 385(9963): 117-71.
2. Kobusingye OC, Hyder AA, Bishai D, Joshipura M, Hicks ER, Mock C. Emergency medical services. Disease Control Priorities in Developing Countries. Washington, D.C.: The International Bank for Reconstruction and Development/The World Bank Group; 2006.
3. Mock C, Joshipura M, Arreola-Risa C, Quansah R. An estimate of the number of lives that could be saved through improvements in trauma care globally. *World journal of surgery* 2012; 36(5): 959-63.
4. Stewart BT, Tansley G, Gyedu A, Ofosu A, Donkor P, Appiah-Denkyira E, et al. Mapping access to essential surgical care in Ghana using availability of Bellwether procedures. *JAMA surgery* 2016; In press.
5. Tansley G, Stewart BT, Zachariah A, Boateng E, Achena C, Mock C. Population-level spatial access to prehospital care by the National Ambulance Service in Ghana. *Prehospital and Emergency Care* 2015; In press.
6. Ankomah J, Stewart BT, Oppong-Nketia V, Koranteng A, Gyedu A, Quansah R, et al. Strategic assessment of the availability of pediatric trauma care equipment, technology and supplies in Ghana. *Journal of pediatric surgery* 2015.
7. Gyedu A, Stewart BT, Nakua E, Quansah R, Donkor P, Mock C, et al. Assessment of risk of peripheral vascular disease and vascular care capacity in low- and middle-income countries. *The British journal of surgery* 2016; 103(1): 51-9.
8. Stewart BT, Quansah R, Gyedu A, Ankomah J, Donkor P, Mock C. Strategic Assessment of Trauma Care Capacity in Ghana. *World journal of surgery* 2015.
9. Gyedu A, Mock C, Nakua E, Otupiri E, Donkor P, Ebel BE. Pediatric First Aid Practices in Ghana: A Population-Based Survey. *World journal of surgery* 2015.
10. Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, et al. Surgical training and experience of medical officers in Ghana's district hospitals. *Academic medicine : journal of the Association of American Medical Colleges* 2011; 86(4): 529-33.

11. Rominski S, Bell SA, Yeboah D, Sarna K, Hartney H, Oteng R. Skills and educational needs of accident and emergency nurses in Ghana: An initial needs analysis. *African Journal of Emergency Medicine* 2011; 1(3): 119-25.
12. Stewart BT, Quansah R, Gyedu A, Boakye G, Abantanga F, Ankomah J, et al. Serial Assessment of Trauma Care Capacity in Ghana in 2004 and 2014. *JAMA surgery* 2015: 1-8.
13. Razzak JA, Kellermann AL. Emergency medical care in developing countries: is it worthwhile? *Bulletin of the World Health Organization* 2002; 80(11): 900-5.
14. Calvello EJ, Tenner AG, Broccoli MC, Skog AP, Muck AE, Tupesis JP, et al. Operationalising emergency care delivery in sub-Saharan Africa: consensus-based recommendations for healthcare facilities. *Emergency medicine journal : EMJ* 2015.
15. Obermeyer Z, Abujaber S, Makar M, Stoll S, Kayden SR, Wallis LA, et al. Emergency care in 59 low- and middle-income countries: a systematic review. *Bulletin of the World Health Organization* 2015; 93(8): 577-86G.
16. Yeboah D, Mock C, Karikari P, Agyei-Baffour P, Donkor P, Ebel B. Minimizing preventable trauma deaths in a limited-resource setting: a test-case of a multidisciplinary panel review approach at the Komfo Anokye Teaching Hospital in Ghana. *World journal of surgery* 2014; 38(7): 1707-12.
17. Data Visualizations: Global Burden of Disease Cause Patterns. 2013. <http://vizhub.healthdata.org/gbd-cause-patterns/> (accessed May 27 2015).
18. Stewart B, Khanduri P, McCord C, Ohene-Yeboah M, Uranues S, Vega Rivera F, et al. Global disease burden of conditions requiring emergency surgery. *British Journal of Surgery* 2014; 101(1): e9-22.
19. Debas HT, Donkor P, Gawande A, Jamison DT, Kruk ME, Mock CN. Essential Surgery. In: Jamison DT, Nugent R, Gelband H, Horton S, Jha P, Laxminarayan R, eds. *Disease Control Priorities, 3rd Edition*. Washington, D.C.: International Bank for Reconstruction and Development / The World Bank; 2015.
20. Sodzi-Tettey S, Aikins M, Awoonor-Williams JK, Agyepong IA. Challenges in provider payment under the Ghana National Health Insurance Scheme: a case study of claims management in two districts. *Ghana medical journal* 2012; 46(4): 189-99.
21. Lagomarsino G, Garabrant A, Adyas A, Muga R, Otoo N. Moving towards universal health coverage: health insurance reforms in nine developing countries in Africa and Asia. *Lancet* 2012; 380(9845): 933-43.

22. McIntyre D, Garshong B, Mtei G, Meheus F, Thiede M, Akazili J, et al. Beyond fragmentation and towards universal coverage: insights from Ghana, South Africa and the United Republic of Tanzania. *Bulletin of the World Health Organization* 2008; 86(11): 871-6.
23. Gyedu A, Baah E.G., Boakye G, Ohene-Yeboah M, Otupiri E, Stewart BT. Quality of referrals for elective surgery at a tertiary care hospital in a developing country: An opportunity for improving timely access to and cost-effectiveness of surgical care. *International journal of surgery* 2015; 15C: 74-8.
24. Mock C, Lormand J, Goosen J, Joshipura M, Peden M. Guidelines for essential trauma care. Geneva: World Health Organization, 2004.

NEXT STEPS

The findings from studies described in the prior chapters and the WHO ECSA process were used to highlight gaps and develop consensus-based action priorities. These were compiled into the report presented in this chapter, which was presented and discussed with the Ghana Ministry of Health officials. From this work and working relationship with national stakeholders, a steering committee was organized to identify partners for implementation of the action priorities, an accountability framework, and a timeline. The entire process was used as the model for subsequent use of WHO ECSA at the national level.

CHAPTER 9 – DISCUSSION

Efforts to improve STC in low-resource settings have relied heavily on capacity assessments to guide development. However, capacity assessments assume that structure (i.e., physical and human resources) is directly proportional to output (i.e., health outcomes, number of cases performed), and neglects processes within the system as well as population factors that affect STC output. Additionally, several recently proposed metrics (e.g., geospatial access to care, risk of catastrophic expenditure when STC is needed and surgical case rate) lacks validation and implementation at a national level, and other process metrics (e.g., American College of Surgeons Committee on Trauma audit filters) are inappropriate for gauging process quality in district- and referral-level hospitals in LMICs. In response, the research detailed in this dissertation provides a comprehensive, multi-level evaluation of the Ghanaian STC system that goes beyond capacity and includes both demand- and supply-side features. This multi-level assessment model and the tools presented herein may be useful for other health systems or countries aiming to identify ways to strengthen their STC system.

CONTRIBUTION TO KNOWLEDGE WITHIN THE FIELD

The work described in this dissertation makes the following important contributions to the field of STC system development:

- Expanded the utility of capacity assessments to include delineation of the causes of resource deficiencies and serial evaluation to inform targeted development interventions;
- Demonstrated that STC capacity and output (i.e., case volume and rate) are not linearly related, suggesting that other non-measured factors are important and should be

measured to more accurately described STC system capabilities;

- Established context-appropriate trauma care audit filters for first- and referral-level hospitals to aid benchmarking and evaluation of quality improvement initiatives;
- Created a reliable and valid tool for assessing barriers to care for patients with essential surgical care needs that can be used in other contexts;
- Piloted the use of STC metrics using prospectively collected national data (e.g., surgical case rate per 100,000 population, geospatial access to STC, risk of catastrophic expenditure when STC needed [see Appendix 14]); and
- Produced a model for rapid, system-wide assessment of emergency and trauma care that goes well beyond capacity, and considers nine domains integral to effective emergency and trauma care delivery.

MAIN FINDINGS AND RELATION TO AIM AND OBJECTIVES

As anticipated, hospitals of all levels across the country demonstrated significant resource deficiencies and performed far too few operations to meet the health needs of their catchment populations. Additionally, assessment of demand-side factors confirmed that much of the population faces significant, varied, and geographically dependent barriers to care and is unable to physically reach essential STC within two hours when care is sought. When the emergency, trauma and surgical system was examined broadly, multiple gaps were uncovered, some of which were underappreciated by the capacity assessment alone. Following discussion of the findings with national stakeholders, a set of action priorities were agreed upon and targeted for interventions aimed at improving the emergency, trauma and surgical care system.

In addition to the standard metrics gained from capacity assessments, the use of novel metrics (e.g., geospatial access to essential STC, risk of catastrophic expenditure when STC is needed, surgical case rate, context-appropriate audit filters, and barriers to essential surgical care) were able to be obtained through either direct data collection or modeling of existing data (e.g., road networks, population density, and hospital capacity). Their use enriched the multilevel assessment and allowed more thorough understanding of what it will take to make substantial improvements to the STC system.

SUMMARY AND CONTEXTUALIZATION OF FINDINGS

Since the three major advocacy achievements in global surgery (i.e., World Health Assembly resolution 68.15, The Lancet Commission on Global Surgery, and The World Bank Disease Control Priorities 3rd Edition Essential Surgical Care) much is being done to develop STC systems in LMICs. In several countries, this is taking shape as efforts to create or integrate STC into national health plans.⁵⁵ However, integrating STC into national health plans demands a thorough understanding of the severity of the deficiencies, credible metrics, measureable interventions, and serial assessment platforms.⁵⁶

Few countries have undertaken a comprehensive, multilevel assessment that provides in-depth understanding of the deficiencies and opportunities as we have done in Ghana.⁵⁷ Countries that have attempted to do so have oft neglected demand-side features, particularly barriers to STC. As a result, any planned interventions on the supply-side, such as those to improve capacity, are unlikely to result in markedly improved outcomes, as they will be out of touch with the needs of the population.⁵⁸ While, current widely used metrics for STC development (i.e., geographic accessibility of surgical facilities, density of specialist surgical providers, surgical case rate,

perioperative mortality rates, risk of impoverishing or catastrophic expenditure when STC is required) include both supply- and demand-side indicators, they do not allow capture of process improvements, increasing capabilities beyond simple capacity improvements, or the potential for health system integration.

During this work, it became apparent that STC does not function without pre-hospital care, emergency department triage and management, rehabilitation, and emergency or disaster preparedness initiatives. Further, to enact change at the national and global levels, a broad coalition is required, which undoubtedly should include the stakeholders in the broader emergency care and health systems. Discounting this relationship might lead to STC being positioned as a silo in global health, much like HIV, malaria, or maternal and child health. Should this occur, the knock-on effects of STC development that could have profoundly positive impacts on a host of conditions (e.g., conditions that benefit from effective pre-hospital care, any condition presenting with shock, and conditions that require rehabilitation) would not be realized. Therefore, a wide spectrum of stakeholders was mobilized to help better position STC within the Ghanaian healthcare system. Together, we envisioned an emergency care system, which included STC, and identified a host of opportunities to improve the system and, ultimately, the health of the population. The implementation of the action priorities identified during this process is now under the purview of the newly created Emergency Care System Steering Committee, which is not government affiliated, but composed of representative stakeholders and endorsed by the Ministry of Health and the Ghana Health Service. The Steering Committee, like other groups working to improve emergency, surgical and trauma care (ESTC) face several hurdles with regards to measuring progress and the effectiveness of interventions, maximizing capabilities, and generating support via advocacy.

First, measuring progress and effectiveness of interventions must be tailored to the context (i.e. be respectful of differences between populations, hospitals, and systems), systematic, and performed serially. The assessments performed in Ghana demonstrated significant nuances, geographic disparities, and problems peculiar to specific populations or hospitals. Therefore, the metrics and assessment strategies have to be sensitive enough to detect such disparate challenges, while being systematic and repeatable across populations and hospitals to aid in comparative operational research and quality improvement.⁵⁹ Many previous assessments have been one-off, which limits the ability to detect changes over time or before and after an intervention.⁷ As was demonstrated by the serial capacity assessment in Ghana, valuable understanding can be achieved when assessments are performed across two or more time points. As the field of global surgery grows, intervention studies aimed at maximizing capabilities and capitalizing on existing resources to reduce the burden of surgical disease will become more common. Serial assessments of the ESTC system may allow the effect of the intervention to be appreciated not only on the intended target(s), but also on other features of the system that may not have been anticipated.⁶⁰ Among the difficulties of systematic and serial assessment is getting ESTC data collection integrated to health information systems designed without EESTC in mind.⁶¹ Some groups have advocated for or attempted ESTC data collection within Demographic and Health Surveys to gather data on disease burden, electronic health systems to gather data on facility-based processes (e.g., audit filters) and assessment of patient outcomes, and more intensive modules to get specific data like perioperative mortality rate and adherence to perioperative care guidelines.⁶¹⁻⁶⁴ Regardless, the variables targeted, frequency of collection, and platform used for compilation, analysis, and dissemination should be tailored to the system's needs and information management strengths to ensure maximal use of the data gathered.⁶⁵

Second, assessment alone is insufficient. Given the enormous unmet need for ESTC in Ghana and other LMICs, interventions to improve access to care and increase service availability and quality are desperately needed.⁴⁴ For example, the barriers to care tool reported herein can be used to identify targets to improve access to care, and assess their impacts. This is currently being done in the Upper East Region of Ghana where the Regional Health Directorate is responding to findings from the study described in Chapter 6. The Health Directorate developed a system to track and communicate with patients who are waiting for elective or semi-elective operations (e.g., herniorrhaphy, and tumor resection). Potentially, this intervention has the opportunity to reduce difficulties associated with navigating the complex healthcare system by having the referral hospital in the region bear some of the follow-up burden instead of the patient. Another example comes from Eastern Region, where the main referral hospital instituted a trauma care and quality improvement training course for providers (e.g., nurses, surgeons, and housestaff). The team collected audit filters before and after the training via a trauma intake form during primary survey and resuscitation, following each surgical encounter, and at discharge or death. While the results have not yet been reported, the study represents excellent use of context-appropriate audit filters for evaluating the effect of an intervention. In response to findings of poor supply chain management practices in the studies that comprise Objectives 1-3, a team has since further examined the supply chain and designed interventions to diversify sources, improve planning for purchases and transport, and prevent stock-outs. The effects of these interventions have not yet been published. However, the results may demonstrate the benefit of strategic capacity assessment and systematic examination of the root causes of deficiencies so that targeted interventions can be developed. As the field of global surgery matures, the use of interventions monitored and evaluated over the long term with systematic and serial assessments will be invaluable.

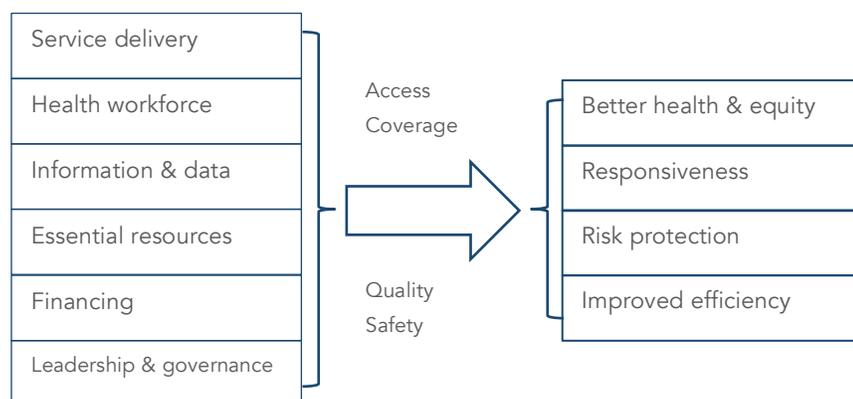
Third, the disconnect between capacity and output in Ghana, as well as reports of differential surgical productivity from other LMICs, highlights the importance of unmeasured factors that play a role in turning capacity into capability, and ultimately, into output.^{39, 66-68} As further work explores these factors (e.g., incentivization schemes, compliance with guidelines, emotional infrastructure, self-agency), they should be included in ESTC and other health service assessments to gain a more rich understanding about capability, beyond availability of essential resources (i.e., capacity). Emotional infrastructure can be used as an example. Hospitals, like all organizations, comprise three types of infrastructure: physical (e.g. facilities, equipment, and supplies); intellectual (e.g. knowledge, skills, and abilities) and emotional.⁶⁹ The latter has been described as an environment that promotes positive feelings among employees and within the organization. The resultant 'perceptible energy' may compel providers to work beyond expectations on behalf of the organization and/or their patients to achieve a shared vision and improve health outcomes.^{69, 70} Currently, there are no emotional infrastructure metrics, thus there is no way for existing assessments to consider this aspect of turning capacity into capability. Further work into the currently unmeasured components of productive, highly capable hospitals may lead to significant improvement in outcomes in systems with varied capacity.

Lastly, the studies herein lay the groundwork for a more complete conceptualization and modeling of capitalization, or the output generated from a set of inputs or costs for ESTC delivery (e.g., resources and functions; and supply) and need (i.e., patient burden and access; and demand). Capitalization may be used as a future, more holistic metric of ESTC development. Additional work needs to identify and characterize simple, valid and feasible means to estimate both delivery and need. By doing so, the return on investment for minimizing barriers to care and optimizing care availability can be understood and tracked.

NEXT STEPS

The findings from these studies have allowed a granular understanding of issues around access to care, ESTC capacity, ECS governance, coordination, and financing, and ways in which these could be addressed. In accordance with the WHO Health System Building Blocks (Figure 3), the Ministry of Health and its implementation partners might achieve gains in important outcomes (e.g., improved health and equity, responsiveness to changes in population needs, risk protection, and improved efficiency). Follow-on work will focus on interventions and implementation of useful interventions in line with this framework.

FIGURE 3. WORLD HEALTH ORGANIZATION HEALTH SYSTEMS BUILDING BLOCKS



The potential gains also fall in line with several of the United Nations (UN) Sustainable Development Goals (SDGs) and would represent an effort toward universal health coverage. All UN Member States have agreed to try to achieve universal health coverage by 2030. Providing care for the ill and injured without risk of catastrophic health expenditure represents a unique opportunity to reduce the burden of injury and strengthen health systems more broadly. Improving the organization and planning for trauma care has been repeatedly shown to reduce death and disability from injury regardless of national income.^{8, 71} For

example, SDGs immediately addressable by improvements in trauma care include:

- SDG 3.4 – by 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being (e.g., injury prevention and surveillance mechanisms, system-wide improvements in trauma care, comprehensive rehabilitation programs);
- SDG 3.5 – strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol (e.g., preventing injuries that would require narcotic pain medications, emergency unit harm reduction interventions);
- SDG 3.6 - by 2020, halve the number of global deaths and injuries from road traffic accidents
 - (e.g., road injury prevention, post-crash care);
- SDG 3.8 – achieve universal health coverage, including financial risk protection, and access to quality essential health-care services (e.g., risk-pooling for emergency conditions and injuries, essential trauma care as a component of national health plans);
- SDG 3.D – strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks (e.g., emergency preparedness, resilient emergency care systems);
- SDG 11.5 - by 2030, significantly reduce the number of deaths and people affected by disasters (e.g., resilient emergency and trauma care systems).

When integrated with local public health and emergency care systems, improving trauma care may also improve care for other high-priority conditions that benefit from systematic surveillance, prompt diagnosis, timely multidisciplinary treatment, and rehabilitation (e.g., sepsis, obstetric emergencies, exacerbations

of non-communicable diseases). The potential for such comprehensive emergency care systems to address a multitude of SDGs is further incentive to invest and implement organized care for the injured.

STRENGTHS AND LIMITATIONS

The work outlined within this dissertation provided a robust, useful, and timely multilevel assessment of the Ghanaian ESTC system. The tools used and the direct application of the data can be used by other health system planners to examine both demand- and supply-side factors that contribute to capacity and output, as well as the ESTC system broadly. In addition to the data produced by the studies, the collaboration and coalition-building between individuals at United States, South African, and Ghanaian academic institutions, and multiple Ghanaian health and related sector actors allowed for robust political engagement and has promoted sustainability through the creation and ongoing work of the stakeholder- and government-endorsed Emergency Care System Steering Committee.

However, several limitations of the work are worth mentioning. First, so little was known about the state of ESTC when the projects began that much of the time was spent performing assessments, designing and validating tools, and exploring metrics. Thus, intervention studies designed to actually improve ESTC capacity were not performed. However, as mentioned above, the Emergency Care System Steering Committee that arose from the stakeholders who took part in this work are actively designing and performing studies to improve the capacity and quality of EESTC in Ghana. Second, a multitude of factors that contribute to the concept of capabilities with the healthcare environment were not explored in detail. Particularly in low-resource settings, it is imperative that the potential

'functionings' of existing capacity be maximized to achieve the greatest benefits for patients despite resource deficiencies. Future work dedicated to operationalization of the capabilities approach in health systems strengthening initiatives would be valuable. Third, although context-appropriate trauma care audit filters were developed for use in Ghana and other LMICs, this work did not validate or use them for quality improvement purposes as the focus was on creating and using assessment approaches and tools. Current work using the audit filters as measures of a training intervention will determine their validity and utility in our context. Lastly, the aspects of this work that intersected with outcomes focused on surgical output. Many other important outcomes exist in ESTC that need to be incorporated into future work, such as perioperative mortality rate, measures of preventable morbidity and mortality, patient satisfaction, changes in access to care, etc. Despite these limitations, the results from the cumulative work presented herein contributed to the tools available for ESTC system assessment and to a small shift in paradigm from resource availability as the gold-standard measure of ESTC to a more comprehensive assessment of both demand- and supply-side factors contributing to capitalization, or the potential return on investment for minimizing barriers to care and optimizing care availability.

CHAPTER 9 - CONCLUSION AND RECOMMENDATIONS

The work underlying this dissertation aimed to develop and model assessments of both demand- and supply-side factors related to ESTC capacity and output in Ghana using both standard and novel metrics to inform a roadmap for ESTC system development. As hypothesized, the assessments demonstrated marked barriers to care and critical deficiencies in ESTC resources nationwide. However, the gaps identified by the assessments allowed action priorities to be established by national stakeholders and a roadmap for ESTC system development to be drafted. Additionally, the work was done in a way that provided a voice for patients through acknowledgement of demand-side issues, and considered unique ways to overcome resource deficiencies through the capabilities approach. Future work stemming from that described herein will likely include incorporating ways to measure processes and the effectiveness of interventions with future assessments, maximize capabilities with existing resources, and generate support via advocacy.

To build on the work herein, the following next steps are recommended:

- Develop continuous, systematic, integrated data collection mechanisms to allow rapid identification of critical capacity gaps, improve the quality of care delivery, and track index outcomes;
- Design and perform intervention studies to reduce barriers to care, strengthen capacity and care delivery, and address the consensus action priorities generated by the WHO ECSA;
- Understand and incorporate evaluation of critical process metrics into ESTC assessments to ensure strong correlation between capacity and outputs;

- Explore and track capitalization as a metric for return on investment for minimizing barriers to care and optimizing ESTC availability;
-
- Advocate for both domestic resource mobilization and international development assistance to address the need for ESTC development in Ghana and other LMICs.

APPENDIX

Appendix 1 – Declarations for first author publications included in the dissertation

Appendix 2 – Ethics and institutional approvals for Objectives 1, 2, 3, 4 and 7

Appendix 2.1 – Conditional Kwame Nkrumah University of Science and Technology Committee on Human Research and Publication Ethics approval to *Strategically Address the Availability of Trauma Care Technology in Ghana*

Appendix 2.2 – Final Kwame Nkrumah University of Science and Technology Committee on Human Research and Publication Ethics approval to *Strategically Address the Availability of Trauma Care Technology in Ghana*

Appendix 2.3 – Ghana Health Service approval to Conduct Research and Assessment of Trauma Related Technology

Appendix 2.4 – Exemption letter from University of Washington Institutional Review Board for *Assessing the Availability of Technology for Trauma Care in Ghana*

Appendix 3 – Additional ethics and institutional approvals for Objective 4

Appendix 3.1 – Kwame Nkrumah University of Science and Technology Committee on Human Research and Publication Ethics approval for Enumeration of Surgical Procedures Performed in Operating Theaters in Ghana

Appendix 3.2 – Christian Health Association of Ghana approval for Hospital Sampling to Determine the Surgical Case Rate in Ghana

Appendix 3.3 – Ghana Health Service approval to Determine the Number and Types of Surgical Procedures Done in Ghana

Appendix 3.4 – Exemption letter from University of Washington Institutional Review Board to Determine the Rates of Operations Performed in Ghana

Appendix 3.5 – Exemption letter from Stellenbosch University for Exploring the Relationship between Surgical Capacity and Output in Ghana

Appendix 4 – Ethics and institutional approvals for Objective 5

Appendix 4.1 – Kwame Nkrumah University of Science and Technology Committee on Human Research and Publication Ethics approval to Evaluation of a Trauma Intake Form for District- and Regional-Level Hospitals in Ghana

Appendix 4.2 – Kwame Nkrumah University of Science and Technology Committee on Human Research and Publication Ethics approval to Evaluation of a Trauma Care Training and Fundamentals of Quality Improvement Course in Ghana

Appendix 4.3 – Ghana Health Service approval to Conduct District and Regional Hospital Trauma Care Training and Quality Improvement Program

Appendix 5 – Ethics and institutional approvals for Objective 6

Appendix 5.1 – Kwame Nkrumah University of Science and Technology Committee on Human Research and Publication Ethics approval to develop and evaluate a Barriers to Surgical Care Assessment Tool for Low- and Middle-Income Countries: A Pilot Study in Ghana

Appendix 5.2 – Ghana Health Service approval to develop and evaluate a Barriers to Surgical Care Assessment Tool for Low- and Middle-Income Countries: A Pilot Study in Ghana

Appendix 6 - Ethics and institutional approvals for Objective 8

Appendix 6.1 – Kwame Nkrumah University of Science and Technology Committee on Human Research and Publication Ethics approval to Evaluate the Impact of Implementation of Consensus-Based Action Priorities on Ghana’s Emergency Care System

Appendix 6.2 – Ghana Health Service approval to Use Information Gathered at the Ghana Emergency Care System Working Group Meeting to Create an Action and Implementation Plan

Appendix 7 - Orthopaedic Trauma Care Capacity Assessment and Strategic Planning in Ghana: Mapping a Way Forward

Appendix 8 - Strategic Assessment of the Availability of Pediatric Trauma Care Equipment, Technology and Supplies in Ghana

Appendix 9 - Availability of resources for emergency care at a second-level hospital in Ghana: A mixed methods assessment

Appendix 10 - Barriers to Essential Surgical Care Experienced by Women in the Two Northernmost Regions of Ghana: A Cross-sectional Survey

Appendix 11 - Assessment of Barriers to Essential Surgical Care in Two Communities in the Upper West Region, Ghana

Appendix 12 - The Birth and Growth of the National Ambulance Service in Ghana

Appendix 13 - Population-level Spatial Access to Prehospital Care by the National Ambulance Service in Ghana

Appendix 14 - The Correlation Between Poverty and Access to Essential Surgical Care in Ghana: A Geospatial Analysis

Appendix 15 - Triage capabilities of medical trainees in Ghana using the South African triage scale: an opportunity to improve emergency care

Appendix 16 – Original approved thesis proposal

Appendix 17 – Amendment to original approved thesis proposal

Appendix 18 – Amendment approval

APPENDIX 1 – DECLARATIONS FOR FIRST AUTHOR
PUBLICATIONS INCLUDED IN THE DISSERTATION

Declaration for Chapter 2

Stewart B. T., Quansah R., Gyedu A., et al. Strategic Assessment of Trauma Care Capacity in Ghana. *World J Surg.* 2015;39(10):2428-40.

With regard to Chapter 2, the nature and scope of my contributions were as follows:

Nature of contribution	Extent of contribution
The PhD candidate designed the study, sought relevant approvals, collected and managed the data, analyzed the data, and drafted the manuscript.	55%

The following co-authors contributed to Chapter 2:

Name	Email	Nature of contribution	Extent of contribution
Robert Quansah	robertquansah@hotmail.com	Assisted with study design, relevant approvals and reviewed the manuscript	5%
Adam Gyedu	drgyedu@gmail.com	Assisted with relevant approvals, data analysis, and review of the manuscript	15%
James Ankomah	kpanin@ymail.com	Assisted with relevant approvals, data collection, and review of the manuscript	5%
Peter Donkor	petadonkor@yahoo.com	Assisted with study design,	5%

		relevant approvals and reviewed the manuscript	
Charles Mock	cmock@uw.edu	Assisted with study design, relevant approvals, data interpretation, and review of the manuscript	15%

Signature of candidate:



Date: 10/1/18

Declaration by co-authors:

The undersigned hereby confirm that:

1. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to this publication,
2. no other authors contributed to this publication besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in this dissertation.

Signature	Name	Institutional affiliation	Date
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	Adam Gyedu	Kwame Nkrumah University of Science and	09 October, 2018

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<i>J.A.*</i>	James Ankomah	Komfo Anokye Teaching Hospital	
<i>P.D.</i>	Peter Donkor	Kwame Nkrumah University of Science and Technology	
<i>Charles Mock</i>	Charles Mock	University of Washington	

Declaration for Chapter 3

Stewart B. T., Quansah R., Gyedu A., et al. Serial Assessment of Trauma Care Capacity in Ghana in 2004 and 2014. *JAMA Surg.* 2015:1-8.

With regard to Chapter 3, the nature and scope of my contributions were as follows:

Nature of contribution	Extent of contribution
The PhD candidate designed the study, sought relevant approvals, collected and managed the data, analyzed the data, and drafted the manuscript.	60%

The following co-authors contributed to Chapter 3:

Name	Email	Nature of contribution	Extent of contribution
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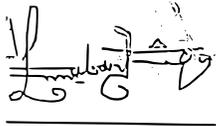
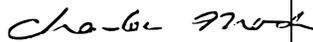
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Signature	Name	Institutional affiliation	Date
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	Charles Mock	University of Washington	

09 October, 2018

Declaration for Chapter 4

Stewart B. T., Gyedu A., Gaskill C., et al. Exploring the Relationship Between Surgical Capacity and Output in Ghana: Current Capacity Assessments May Not Tell the Whole Story. *World J Surg.* 2018 Oct;42(10):3065-3074

With regard to Chapter 4, the nature and scope of my contributions were as follows:

Nature of contribution	Extent of contribution
The PhD candidate designed the study, sought relevant approvals, collected and managed the data, analyzed the data, and drafted the manuscript.	60%

The following co-authors contributed to Chapter 4:

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Signature of candidate:

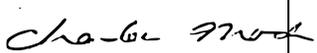


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Declaration by co-authors:

The undersigned hereby confirm that:

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2. no other authors contributed to this publication besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in this dissertation.

Signature	Name	Institutional affiliation	Date
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Declaration for Chapter 5

Stewart B. T., Gyedu A., Quansah R., et al. District-level hospital trauma care audit filters: Delphi technique for defining context-appropriate indicators for quality improvement initiative evaluation in developing countries. *Injury*. 2016;47(1):211-9.

With regard to Chapter 5, the nature and scope of my contributions were as follows:

Nature of contribution	Extent of contribution
The PhD candidate designed the study, sought relevant approvals, collected and managed the data, analyzed the data, and drafted the manuscript.	60%

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1. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to this publication,
2. no other authors contributed to this publication besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in this dissertation.

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Declaration for Chapter 6

Stewart B. T., Gyedu A., Abantanga F., et al. Barriers to Essential Surgical Care in Low- and Middle-Income Countries: A Pilot Study of a Comprehensive Assessment Tool in Ghana. *World J Surg.* 2015. Nov;39(11):2613-21

With regard to Chapter 6, the nature and scope of my contributions were as follows:

Nature of contribution	Extent of contribution
The PhD candidate designed the study, sought relevant approvals, collected and managed the data, analyzed the data, and drafted the manuscript.	60%

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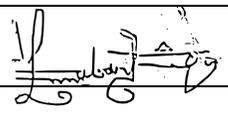


Date: 10/1/18

Declaration by co-authors:

The undersigned hereby confirm that:

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2. no other authors contributed to this publication besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in this dissertation.

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	Adam Kushner	Johns Hopkins Bloomberg School of Public Health	

Declaration for Chapter 7

Stewart B. T., Tansley G., Gyedu A., et al. Mapping Population-Level Spatial Access to Essential Surgical Care in Ghana Using Availability of Bellwether Procedures. *JAMA Surg.* 2016;151(8):e161239.

With regard to Chapter 7, the nature and scope of my contributions were as follows:

Nature of contribution	Extent of contribution
The PhD candidate designed the study, sought relevant approvals, collected and managed the data, analyzed the data, and drafted the manuscript.	55%

The following co-authors contributed to Chapter 7:

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Charles Mock	cmock@uw.edu	Assisted with relevant approvals, study design, data interpretation, and reviewed the manuscript	5%

Signature of candidate:



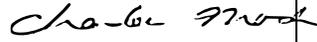
Date: 10/1/18

Declaration by co-authors:

The undersigned hereby confirm that:

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2. no other authors contributed to this publication besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in this dissertation.

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	Ebenezer Appiah-Denkyira	Ghana Health Service	
	Robert Quansah	Kwame Nkrumah	

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	Damian Clarke	University of Kwa- Zulu Natal	
	Jimmy Volmink	Stellenbosch University	
	Charles Mock	University of Washington	

Declaration for Chapter 8

Consensus-Based Action Priorities From an Assessment of the Ghana Emergency Care System: A Roadmap for Development. Geneva, Switzerland: World Health Organization, 2016 May 5, 2016

With regard to Chapter 8, the nature and scope of my contributions were as follows:

Nature of contribution	Extent of contribution
The PhD candidate designed the study, sought relevant approvals, collected and managed the data, analyzed the data, and drafted the manuscript.	80%

Although a host of individuals (listed in the text) participated in the assessment and conference, only 2 co-authors directly contributed to the writing of Chapter 8:

Name	Email	Nature of contribution	Extent of contribution
Adam Gyedu	drgyedu@gmail.com	Assisted with relevant approvals, study design, data analysis, and review of the manuscript	10%
Charles Mock	cmock@uw.edu	Assisted with relevant approvals, study design, data analysis, and review of the manuscript	10%

Signature of candidate:



Date: 10/1/18

Declaration by co-authors:

The undersigned hereby confirm that:

1. the declaration above accurately reflects the nature and extent of the contributions of the candidate and the co-authors to this publication,
2. no other authors contributed to this publication besides those specified above, and
3. potential conflicts of interest have been revealed to all interested parties and that the necessary arrangements have been made to use the material in this dissertation.

Signature	Name	Institutional affiliation	Date
	Adam Gyedu	Kwame Nkrumah University of Science and Technology	09 October, 2018
	Charles Mock	University of Washington	

*Three co-authors did not respond to request for signature of this declaration form. However, they completed declarations forms for each of the manuscripts they co-authored prior to publication. Their contributions can be found within the published article in each Chapter.

APPENDIX 2 – ETHICS AND INSTITUTIONAL APPROVALS FOR OBJECTIVES 1, 2, 3, 4 AND 7

APPENDIX 2.1 – CONDITIONAL KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY COMMITTEE ON HUMAN RESEARCH AND PUBLICATION ETHICS APPROVAL TO STRATEGICALLY ADDRESS THE AVAILABILITY OF TRAUMA CARE TECHNOLOGY IN GHANA



KWAME NKURUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF HEALTH SCIENCES



SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL
COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/RC/224/14

27th June, 2014.

Prof. Peter Donkor
Department of Surgery
Komfo Anokye Teaching Hospital
Post Office Box 1934
KUMASI.

Dear Sir,

ETHICS REVIEW COMMENTS – CONDITIONAL APPROVAL

Protocol Title: "Strategically Address the Availability of Technology for Trauma Care."

Following a full Committee review, your protocol was given a conditional approval subject to you addressing the following concerns/queries:

On the CHRPE Form:

Item 2.6: 1. The inclusion criteria should be provided.

Item 2.10: 2. We recommend that records should be retained for at least 3 years. Hard copies should be under lock and key and soft copies should be password protected. Please revise.

Kindly make the necessary amendments and submit one copy of the document(s) you have been asked to correct to the CHRPE (Room 7 Block J, School of Medical Sciences, KNUST), along with a letter explaining the changes you have made to the document(s). The date and reference number of this letter should be quoted in your letter.

Thank you Sir, for your application.

Yours faithfully,

Rev. Prof. John Appiah-Poku
Honorary Secretary
FOR: CHAIRMAN

APPENDIX 2.2 – FINAL KWAME NKURUMAH UNIVERSITY OF
SCIENCE AND TECHNOLOGY COMMITTEE ON HUMAN RESEARCH
AND PUBLICATION ETHICS APPROVAL TO *STRATEGICALLY ADDRESS
THE AVAILABILITY OF TRAUMA CARE TECHNOLOGY IN GHANA*



KWAME NKURUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF HEALTH SCIENCES



SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL
COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/279/14

22nd August, 2014.

Prof. Peter Donkor
Department of Surgery
Komfo Anokye Teaching Hospital
Post Office Box 1934
KUMASI.

Dear Sir,

LETTER OF APPROVAL

Protocol Title: "Strategically Address the Availability of Technology for Trauma Care"

Proposed Site: District and Regional Hospitals in Several Regions of Ghana.

Sponsor: Fogarty International Center, US NIH.

Your submission to the Committee on Human Research, Publications and Ethics on the above named protocol refers.

The Committee reviewed the following documents:

- A notification letter of 29th May, 2014 from the Ghana Health Service (study site) indicating approval for the conduct of the study under the Ghana Health Service
- A completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Proposal.
- Assessment Form.

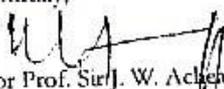
The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, renewable annually thereafter. The Committee may however, suspend or withdraw ethical approval at anytime if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Thank you Sir, for your application.

Yours faithfully,


Osomfuor Prof. Sir J. W. Acheampong MD, FWACP
Chairman

APPENDIX 2.3 – GHANA HEALTH SERVICE APPROVAL TO CONDUCT
RESEARCH AND ASSESSMENT OF TRAUMA RELATED TECHNOLOGY

In case of reply the number and the date of this letter should be quoted

My Ref. No. GHS/DGS/ K-5

Your Ref. No.



Ghana Health Service
Private Mail Bag
Ministries
Accra-Ghana

Tel: 0302 662 014
Fax: 0302 666 808
E-mail: dg@ghsmail.org

29 May 2014

PROF PETER DONKOR
PRINCIPAL INVESTIGATOR
KWAME NKRUMAH UNIV. OF SCIENCE & TECHNOLOGY
COLLEGE OF HEALTH SCIENCES
SCHOOL OF MEDICAL SCIENCES
PMB, UNIVERSITY POST OFFICE
KUMASI

Dear Prof,

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH ON TRAUMA RELATED TECHNOLOGY

Your letter dated 27th May, 2014 regarding the above-mentioned subject refers.

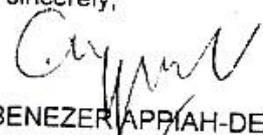
I wish to inform you that approval has been granted for the conduct of the research titled "Strategically address the availability of technology for Trauma Care" in hospitals under the Ghana Health Service.

The approval is subject to the granting of ethical clearance from the appropriate Ethical Body.

It is my belief that the outcome of the research will inform any decision making on strengthening trauma care.

Thank you.

Yours sincerely,


DR EBENEZER APPIAH-DENKYIRA
DIRECTOR GENERAL
GHANA HEALTH SERVICE

Cc: All Regional Directors of Health Service

APPENDIX 2.4 – EXEMPTION LETTER FROM UNIVERSITY OF
WASHINGTON INSTITUTIONAL REVIEW BOARD FOR *ASSESSING THE
AVAILABILITY OF TECHNOLOGY FOR TRAUMA CARE IN GHANA*



UNIVERSITY of WASHINGTON

HUMAN SUBJECTS DIVISION

Date: February 24, 2014

PI: Dr. Charles Mock
Professor
Global Health

RE: HSD study #46955
"Assessing the availability of technology for trauma care in hospitals in Ghana"

Dear Dr. Mock:

The University of Washington Human Subjects Division (HSD) has determined that your research qualifies for exempt status in accordance with the federal regulations under 45 CFR 46.101/ 21 CFR 56.104. Details of this determination are as follows:

Exempt category determination: **Category 2**

Determination period: **2/24/2014 - 2/23/2019**

Although research that qualifies for exempt status is not governed by federal requirements for research involving human subjects, investigators still have a responsibility to protect the rights and welfare of their subjects, and are expected to conduct their research in accordance with the ethical principles of *Justice, Beneficence* and *Respect for Persons*, as described in the Belmont Report, as well as with state and local institutional policy.

Determination Period: An exempt determination is valid for five years from the date of the determination, as long as the nature of the research activity remains the same. If there is any substantive change to the activity that has determined to be exempt, one that alters the overall design, procedures, or risk/benefit ratio to subjects, the exempt determination will no longer be valid. Exempt determinations expire automatically at the end of the five-year period. If you complete your project before the end of the determination period, it is not necessary to make a formal request that your study be closed. Should you need to continue your research activity beyond the five-year determination period, you will need to submit a new *Exempt Status Request* form for review and determination *prior to implementation*.

Revisions: Only modifications that are deemed "minor" are allowable, in other words, modifications that do not change the nature of the research and therefore do not affect the validity of the exempt determination. **Please refer to the Guidance document for more information about what are considered minor changes.** If changes that are considered to be "substantive" occur to the research, that is, changes that alter the nature of the research and therefore affect the validity of the exempt determination, a new *Exempt Status Request* must be submitted to HSD for review and determination *prior to implementation*.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events or any problem that may increase the risk to the human subjects and change the category of review, notify HSD promptly. Any complaints from subjects pertaining to the risk and benefits of the research must be reported to HSD.

Please use the HSD study number listed above on any forms submitted which relate to this research, or on any correspondence with the HSD office.

Good luck in your research. If we can be of further assistance, please contact us at (206) 543-0098 or via email at hsdinfo@uw.edu. Thank you for your cooperation.

Sincerely,

Kristin Puhl, MS
Human Subjects Review Coordinator
(206) 543-3494
puhlkc@uw.edu

APPENDIX 3 – ADDITIONAL ETHICS AND INSTITUTIONAL APPROVALS FOR OBJECTIVE 4

APPENDIX 3.1 – KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY COMMITTEE ON HUMAN RESEARCH AND PUBLICATION ETHICS APPROVAL FOR ENUMERATION OF SURGICAL PROCEDURES PERFORMED IN OPERATING THEATERS IN GHANA



KWAME NKUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF HEALTH SCIENCES



SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL
COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/234/15

29th May, 2015.

Prof. Robert Quansah
Department of Surgery
Komfo Anokye Teaching Hospital
KUMASI.

Dear Sir,

LETTER OF APPROVAL

Protocol Title: "Enumeration of Procedures Performed in Operating Theatres in Ghana."

Proposed Site: District, Regional and Tertiary Hospitals in Ghana.

Sponsor: Principal Investigator.

Your submission to the Committee on Human Research, Publications and Ethics on the above named protocol refers.

The Committee reviewed the following documents:

- A notification letter of 17th March, 2015 from the Ghana Health Service (study site) indicating approval for the conduct of the study in the above-mentioned Hospitals.
- A notification letter of 15th April, 2015 from the Komfo Anokye Teaching Hospital (study site) indicating approval for the conduct of the study in the Hospital.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.
- Case Record Form.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, renewable annually thereafter. The Committee may however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Thank you Sir, for your application.

Yours faithfully,

Rev. Prof. John Appiah-Poku
Honorary Secretary
FOR: CHAIRMAN

APPENDIX 3.2 – CHRISTIAN HEALTH ASSOCIATION OF GHANA
APPROVAL FOR HOSPITAL SAMPLING TO DETERMINE THE
SURGICAL CASE RATE IN GHANA



CHRISTIAN HEALTH ASSOCIATION OF GHANA

#21, Jubilee Well Street, Labone • P.O. Box AN 7316, Accra • Phone: +233 (0) 30 277 7815 • Fax: +233 (0) 30 277 2226
Email: chag@chag.org.gh • Web: www.chag.org.gh

Our Ref. : **CHAG/H4**

May 13, 2015

Serial No : **150029**

Your Ref. :

RE: HOSPITAL SAMPLING FOR SURGERY CASE RATE DETERMINATION IN GHANA

We introduce to you, a research Team from the College of Health Sciences - School of Medical Sciences, Department of Surgery of the Kwame Nkrumah University of Sciences and Technology (KNUST), Kumasi.

They are undertaking a study in Surgery Case Rate Determination in Ghana and have identified your facility to be a sampling site. The Team would visit your facility from May 18th through to August 1st, 2015.

Consequently, we entreat you to accord them the necessary assistance.

Thank you.

PETER K. YEBOAH
EXECUTIVE DIRECTOR

Distribution

1. The Hospital Administrator, St. Martin de Porres Hospital, Eikwe
2. The Hospital Administrator, St. John of God Hospital, Sefwi Asafo
3. The Hospital Administrator, Holy Family Hospital, Techiman
4. The Hospital Administrator, St. Patrick's Hospital, Offinso
5. The Hospital Administrator, St. Francis Xavier Hospital, Assin Fosu
6. The Hospital Administrator, Akomaa Mem SDA Hospital, Kortwia
7. The Hospital Administrator, Mary Theresa Hospital, Dodi Papase
8. The Hospital Administrator, St. Elizabeth Hospital, Hwidiem
9. The Hospital Administrator, Holy Family Hospital, Berekum
10. The Hospital Administrator, St. John of God Hospital, Duayaw Nkwanta
11. The General Manager, Presbyterian Hospital, Dormaa Ahenkro
12. The General Manager, Presbyterian Hospital, Agogo

Cc: The Research Team, College of Health Sciences, School of Medical Sciences, KNUST, Kumasi

APPENDIX 3.3 – GHANA HEALTH SERVICE APPROVAL TO
DETERMINE THE NUMBER AND TYPES OF SURGICAL PROCEDURES
DONE IN GHANA

In case of reply the number and the date of this letter should be quoted



Ghana Health Service
Private Mail Bag
Ministries
Accra-Ghana

My Ref. No. GHS/DGS/K-5

Tel: 662014
Fax: 666808

Our Ref No.

17 March, 2015

Prof Robert Quansah
Principal Investigator
Kwame Nkrumah University of Science and Technology
College of Health Sciences
School of Medical Sciences
Pmb University Post Office
Kumasi

Dear Prof,

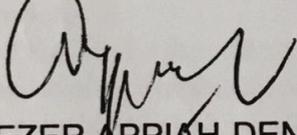
RE: REQUEST FOR PERMISSION TO DETERMINE THE NUMBER AND TYPES OF SURGICAL PROCEDURES DONE IN GHANA

Your letter dated 17th March, 2015 regarding the above-mentioned subject refers.

I wish to inform you that approval has been granted to enumerate the type of surgical procedures done in Ghana from district and regional hospitals.

It is my belief that Ghana is in need of a benchmark of surgical volume and case mix from which capacity improvement interventions and healthcare development over time could be assessed.

Yours sincerely,



DR EBENEZER APPIAH-DENKYIRA
DIRECTOR GENERAL
GHANA HEALTH SERVICE

Cc: All Regional Directors of Health Service

APPENDIX 3.4 – EXEMPTION LETTER FROM UNIVERSITY OF
WASHINGTON INSTITUTIONAL REVIEW BOARD TO DETERMINE THE
RATES OF OPERATIONS PERFORMED IN GHANA

UNIVERSITY OF WASHINGTON
SEATTLE, WASHINGTON 98195-9470

*Human Subjects Division Box 359470
Office of Research*

May 28, 2015

To: Professor Charles Mock, MD

From: Geri C. Faris, Administrator

Re: Determination of Exemption #49825, "Rates of Operations Per Population in Ghana"

Dr. Mock,

The University of Washington Human Subjects Division (HSD) has determined that your research qualifies for exempt status in accordance with the federal regulations under 45 CFR 46.101/ 21 CFR 56.104. Details of this Human Subjects determination are as follows:

Exempt category determination: **Category #4**
Determination period is from: 5/28/2015 – 5/27/2020

Although research that qualifies for exempt status is not governed by federal requirements for research involving human subjects, investigators still have a responsibility to protect the rights and welfare of their subjects, and are expected to conduct their research in accordance with the ethical principles of *Justice*, *Beneficence* and *Respect for Persons* described in the Belmont Report as well as state and local institutional policy.

Determination Period: An exempt determination is valid for five years from the date of the determination, as long as the nature of the research activity remains the same. If there is any substantive change to the activity that has determined to be exempt, such that the overall design, procedures, or risk/benefit ratio to subjects is altered, the exempt determination will no longer be valid. It is not necessary to formally request that your study be closed. Should you need to continue your research activity beyond the five-year determination period, you will need to submit a new *Request for Determination of Exempt Status* form for review and determination *prior to implementation*.

Revisions: Only modifications that are deemed "minor" are allowable, given that they do not change the nature of the research and therefore the validity of the exempt determination. Please refer to the Guidance document for more information about what are considered minor changes. If changes occur to the research that are considered to be "substantive", such that they change the nature of the research and therefore the validity of the exempt determination, a new *Request for Determination of Exempt Status* must be submitted to HSD as a new exempt determination for review and determination *prior to implementation*.

Problems: If issues should arise during the conduct of the research, such unanticipated problems, adverse events or any problem that may increase the risk to the human subjects and change the category of review, notify the HSD promptly. Any complaints from subjects regarding the risk and benefits of the research must be reported to HSD.

Please use the HSD study number listed above on any forms submitted which relate to this research, or on any correspondence with the HSD office. If we can be of further assistance, please contact us at (206) 543-0098 or via email at hsdinfo@uw.edu. Best wishes for your research.

APPENDIX 3.5 – EXEMPTION LETTER FROM STELLENBOSCH
UNIVERSITY FOR EXPLORING THE RELATIONSHIP BETWEEN
SURGICAL CAPACITY AND OUTPUT IN GHANA



Ethics Exemption Letter

09-Apr-2018

HREC Reference #: X18/04/010

Title: Exploring the Relationships Between Surgical Capacity and Output in Ghana: Current Capacity Assessments May Not Tell the Whole Story

Dear Dr Barclay Stewart,

Thank you for your application to our Health Research Ethics Committee (HREC) dated 20 February 2018. The HREC has noted that above referenced study received ethics approvals from the Kwame Nkrumah University of Science and Technology School of Medical Sciences' Committee on Human Research, Publication & Ethics and the University of Washington Human Subjects Division. It is also noted that the study was conducted in Ghana after obtaining relevant ethics approvals. Therefore, the Health Research Ethics Committee considers this application to be exempt from ethics review. You may therefore proceed with publication of the findings.

Please note the following information about your approved ethics exemption:

Approval Period: **09-Apr-2018 – 08-Apr-2019**

Please remember to use your **HREC Reference Number [X18/04/010]** on any documents or correspondence with the HREC concerning your research protocol.

After Ethical Review

Please note that you can submit your progress report through the online ethics application process, available at: <https://applyethics.sun.ac.za> and the application should be submitted to the Committee before the year has expired. Please see Forms and Instructions on our HREC website for guidance on how to submit a progress report.

The Committee will then consider the continuation of the project for a further year (if necessary). Annually a number of projects may be selected randomly for an external audit.

For standard HREC forms and instructions, please visit: Forms and Instructions on our HREC website Links Application Form Direct Link.

Provincial and City of Cape Town Approval

Please note that for research at a primary or secondary healthcare facility, permission must still be obtained from the relevant authorities (Western Cape Department of Health and/or City Health) to conduct the research as stated in the protocol. Please consult the Western Cape Government website for access to the online Health Research Approval Process, see: <https://www.westerncape.gov.za/general-publication/health-research-approval-process>. Research that will be conducted at any tertiary academic institution requires approval from the



STELLENBOSCH UNIVERSITY
Health Research Ethics Committee
Fakulteit Geneeskunde en Gesondheidswetenskappe
Faculty of Health and Health Sciences
09 APR 2018



STELLENBOSCH UNIVERSITEIT
Gesondheidsnavorsing Etyiek Komitee

Afdeling Navorsings- en Opleidingsontwikkeling Health Research Development and Support Division



relevant hospital manager. Ethics approval is required BEFORE approval can be obtained from these health authorities.

We wish you the best as you conduct your research.

If you have any questions or need further assistance, please contact the HREC office at 021 938 9677.

National Health Research Ethics Council (NHREC) Registration Numbers: REC-130408-012 for HREC1 and REC-230208-010 for HREC2

Federal Wide Assurance Number: 00001372

Institutional Review Board (IRB) Number: IRB0005240 for HREC1

Institutional Review Board (IRB) Number: IRB0005239 for HREC2

The Health Research Ethics Committee complies with the SA National Health Act No. 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 Part 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles, Structures and Processes 2015 (Departement of Health).

Yours sincerely,

Francis Masiye,
HREC Coordinator,
Health Research Ethics Committee 2.

STELLENBOSCH UNIVERSITY
Health Research Ethics Committee

09 APR 2018

STELLENBOSCH UNIVERSITEIT
Gesondheidsnavorsing Etekkomitee



Fakulteit Geneeskunde en Gesondheidswetenskappe
Faculty of Medicine and Health Sciences



APPENDIX 4 – ETHICS AND INSTITUTIONAL APPROVALS FOR OBJECTIVE 5

APPENDIX 4.1 – KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY COMMITTEE ON HUMAN RESEARCH AND PUBLICATION ETHICS APPROVAL TO EVALUATION OF A TRAUMA INTAKE FORM FOR DISTRICT- AND REGIONAL-LEVEL HOSPITALS IN GHANA



SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL
COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/295/15

5th August, 2015.

Prof. Robert Quansah
Department of Surgery
Komfo Anokye Teaching Hospital
Post Office Box 1934
KUMASI.

Dear Sir,

LETTER OF APPROVAL

Protocol Title: "Evaluation of a Trauma Intake Form for District-Level and Regional Hospitals in Ghana."

Proposed Site: Ghana Health Service-Two Regional and Six District Hospitals.

Sponsor: Principal Investigator.

Your submission to the Committee on Human Research, Publications and Ethics on the above named protocol refers.

The Committee reviewed the following documents:

- A notification letter of 17th March, 2015 from the Ghana Health Service (study site) indicating approval for the conduct of the study in the Hospitals.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.
- Data Capturing Tool.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, renewable annually thereafter. The Committee may however, suspend or withdraw ethical approval at anytime if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Thank you Sir, for your application.

Yours faithfully,

Osomfuor Prof. Sir J. W. Acheampong MD, FWACP
Chairman

APPENDIX 4.2 – KWAME NKRUMAH UNIVERSITY OF SCIENCE AND
TECHNOLOGY COMMITTEE ON HUMAN RESEARCH AND
PUBLICATION ETHICS APPROVAL TO EVALUATION OF A TRAUMA
CARE TRAINING AND FUNDAMENTALS OF QUALITY IMPROVEMENT
COURSE IN GHANA



Our Ref: CHRPE/AP/127/15

14th April, 2015.

Prof Robert Quansah
Department of Surgery
Komfo Anokye Teaching Hospital
KUMASI-GHANA.

Dear Sir,

LETTER OF APPROVAL

Protocol Title: "Evaluation of a Trauma Care Training and Fundamentals of Quality Improvement Programs Course."

Proposed Site: 3 District Hospitals in the Central Region, 3 District Hospitals in the Eastern Region.

Sponsor: Principal Investigator.

Your submission to the Committee on Human Research, Publications and Ethics on the above named protocol refers.

The Committee reviewed the following documents:

- A notification letter of 17th March, 2015 from the Ghana Health Service (study site) indicating approval for the conduct of the study in the 6 selected Hospitals.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.
- Focus Group Interview Guide.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, renewable annually thereafter. The Committee may however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Thank you Sir, for your application.

Yours faithfully,

Osomfuor Prof. Sir J. W. Acheampong MD, FWACP
Chairman

APPENDIX 4.3 – GHANA HEALTH SERVICE APPROVAL TO CONDUCT
DISTRICT AND REGIONAL HOSPITAL TRAUMA CARE TRAINING AND
QUALITY IMPROVEMENT PROGRAM

In case of reply the number and the date of this letter should be quoted



Ghana Health Service
Private Mail Bag
Ministries
Accra-Ghana

My Ref. No. GHS/DGS/K-5

Tel: 662014
Fax: 666808

Our Ref No.

17 March, 2015

Prof Robert Quansah
Principal Investigator
Kwame Nkrumah University of Science and Technology
College of Health Sciences
School of Medical Sciences
PMB University Post Office
Kumasi

Dear Prof,

RE: REQUEST FOR PERMISSION TO CONDUCT DISTRICT AND REGIONAL HOSPITAL TRAUMA CARE TRAINING AND QUALITY IMPROVEMENT PROGRAM

Your letter dated 17th March, 2015 regarding the above-mentioned subject refers.

I wish to inform you that approval has been granted for the conduct of trauma care training and quality improvement program at district and regional hospitals under the care of the Ghana Health Service.

It is my belief that trauma training and quality improvement programs will improve care for the injured in Ghana and strengthen health service delivery more broadly.

Yours sincerely,

DR EBENEZER APPIAH-DENKYIRA
DIRECTOR GENERAL
GHANA HEALTH SERVICE

Cc: All Regional Directors of Health Service

APPENDIX 5 – ETHICS AND INSTITUTIONAL APPROVALS FOR OBJECTIVE 6

APPENDIX 5.1 – KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY COMMITTEE ON HUMAN RESEARCH AND PUBLICATION ETHICS APPROVAL TO DEVELOP AND EVALUATE A BARRIERS TO SURGICAL CARE ASSESSMENT TOOL FOR LOW- AND MIDDLE-INCOME COUNTRIES: A PILOT STUDY IN GHANA



SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL
COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/391/14

18th December, 2014.

Prof. Francis Abantanga
Department of Surgery
Komfo Anokye Teaching Hospital
Post Office Box 1934
KNUST-KUMASI.

Dear Sir,

LETTER OF APPROVAL

Protocol Title "Barriers to Surgical Care in Low- and Middle- Income Countries Assessment Tool: A Pilot Study in Ghana."

Proposed Site: Some Selected Communities in the Upper East Region.

Sponsor: Principal Investigator.

Your submission to the Committee on Human Research, Publications and Ethics on the above named protocol refers.

The Committee reviewed the following documents:

- A notification letter of 29th November 2014 from the Upper East Regional Hospital (study site) indicating approval for the conduct of the study in the Region.
- A completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Proposal.
- Questionnaire.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, renewable annually thereafter. The Committee may however, suspend or withdraw ethical approval at anytime if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Thank you Sir, for your application.

Yours faithfully,

Osomfuor Prof. Sir J. W. Acheampong MD, FWACP
Chairman

APPENDIX 5.2 – GHANA HEALTH SERVICE APPROVAL TO DEVELOP
AND EVALUATE A BARRIERS TO SURGICAL CARE ASSESSMENT TOOL
FOR LOW- AND MIDDLE-INCOME COUNTRIES: A PILOT STUDY IN
GHANA

*In case of reply the
number and date of this
Letter should be quoted.*

My Ref GHS/BRH/

Your Ref. No



Regional Hospital,
Ghana Health Services,
P. O. Box 26 ,
Bolgatanga, UER.

Date: 29th November, 2014
Tel: (03820) 22461
Fax: (03820) 22216

**THE CHAIRMAN
THE COMMITTEE ON HUMAN RESEARCH, PUBLICATIONS AND ETHICS
KNUST-SMS/KATH
KUMASI**

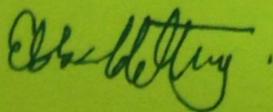
Dear Sir,

**APPLICATION FOR ETHICAL CLEARANCE FOR THE STUDY TITLED "BARRIERS
TO SURGICAL CARE IN LOW- AND MIDDLE- INCOME COUNTRIES ASSESSMENT
TOOL: A PILOT STUDY IN GHANA"**

A number of barriers prevent patients from receiving essential surgery. The present study aims to pilot an assessment tool aimed at identifying barriers of availability, affordability and acceptability to essential surgery. A validated tool of this nature will help in targeting interventions to minimize the effect of specific barriers.

We write in support of the application for ethical clearance for the study. We look forward to data from the study informing our policies and interventions

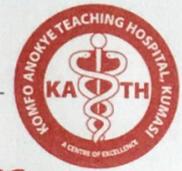
Yours Sincerely,



**PETER BAFFOE
MD, OBGYN, FGCS, MPH.
MEDICAL DIRECTOR.**

APPENDIX 6 – ETHICS AND INSTITUTIONAL APPROVALS FOR OBJECTIVE 8

APPENDIX 6.1 – KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY COMMITTEE ON HUMAN RESEARCH AND PUBLICATION ETHICS APPROVAL TO EVALUATE THE IMPACT OF IMPLEMENTATION OF CONSENSUS-BASED ACTION PRIORITIES ON GHANA’S EMERGENCY CARE SYSTEM



SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL
COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/423/16

15th September, 2016.

Prof. Robert Quansah
Department of Surgery
School of Medical Sciences
KNUST-KUMASI

Dear Sir,

LETTER OF APPROVAL

Protocol Title: *“Evaluating the Impact of Implementation of Consensus-Based Action Priorities on Ghana’s Emergency Care System.”*

Proposed Site: *The Conference Room of the Ghana Health Service.*

Sponsor: **Principal Investigator.**

Your submission to the Committee on Human Research, Publications and Ethics on the above named protocol refers.

The Committee reviewed the following documents:

- A notification letter of 1st April, 2016 from Ghana Health Service, Accra (study site) indicating approval for the conduct of the study in the Hospital.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent form.
- Research Protocol.
- Assessment Tool.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, beginning 15th September, 2016 to 14th September, 2017 renewable thereafter. The Committee may however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Yours faithfully,

Rev. Prof. John Appiah-Poku

Honorary Secretary
FOR: CHAIRMAN

APPENDIX 6.2 – GHANA HEALTH SERVICE APPROVAL TO USE
INFORMATION GATHERED AT THE GHANA EMERGENCY CARE
SYSTEM WORKING GROUP MEETING TO CREATE AN ACTION AND
IMPLEMENTATION PLAN

In case of reply the number and the date of this letter should be quoted

My Ref. No. GHS/DGS/G.2

Your Ref No.



Ghana Health Service
Private Mail Bag
Ministries
Accra-Ghana

Tel: 0302 662 014

Fax: 0302 666 808

E-mail: dg@ghsmail.org

1 April 2016

PROF ROBERT QUANSAH
PRINCIPAL INVESTIGATOR
KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF HEALTH SCIENCES
SCHOOL OF MEDICAL SCIENCES
PMB UNIVERSITY POST OFFICE
KUMASI

Dear Prof,

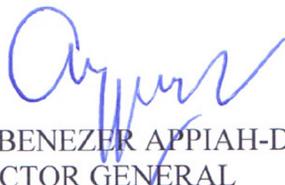
**RE: REQUEST FOR PERMISSION TO USE INFORMATION GATHERED AT THE
GHANA EMERGENCY CARE SYSTEM WORKING GROUP MEETING TO CREATE AN
ACTION AND IMPLEMENTATION PLAN**

I wish to inform you that approval has been granted for the conduct of an assessment of Ghana's emergency care system and follow up with a meeting to prepare an action and implementation plan.

This plan can be published as an example for other countries attempting similar work.

It is my belief that this work has the potential to organise emergency care action priorities in a way that is use ful for implementation in our setting.

Yours sincerely,



DR EBENEZER APPIAH-DENKYIRA
DIRECTOR GENERAL
GHANA HEALTH SERVICE

**APPENDIX 7 - ORTHOPAEDIC TRAUMA CARE CAPACITY
ASSESSMENT AND STRATEGIC PLANNING IN GHANA:
MAPPING A WAY FORWARD**

THE ORTHOPAEDIC FORUM

Orthopaedic Trauma Care Capacity Assessment and Strategic Planning in Ghana: Mapping a Way Forward

Barclay T. Stewart, MD, MScPH, Adam Gyedu, MD, MPH, Gavin Tansley, MD, Dominic Yeboah, MD, MPH, Forster Amponsah-Manu, MD, Charles Mock, MD, PhD, Wilfred Labi-Addo, MD, and Robert Quansah, MD, PhD

Investigation performed at the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Background: Orthopaedic conditions incur more than 52 million disability-adjusted life years annually worldwide. This burden disproportionately affects low and middle-income countries, which are least equipped to provide orthopaedic care. We aimed to assess orthopaedic capacity in Ghana, describe spatial access to orthopaedic care, and identify hospitals that would most improve access to care if their capacity was improved.

Methods: Seventeen perioperative and orthopaedic trauma care-related items were selected from the World Health Organization's *Guidelines for Essential Trauma Care*. Direct inspection and structured interviews with hospital staff were used to assess resource availability and factors contributing to deficiencies at 40 purposively sampled facilities. Cost-distance analyses described population-level spatial access to orthopaedic trauma care. Facilities for targeted capability improvement were identified through location-allocation modeling.

Results: Orthopaedic trauma care assessment demonstrated marked deficiencies. Some deficient resources were low cost (e.g., spinal immobilization, closed reduction capabilities, and prosthetics for amputees). Resource nonavailability resulted from several contributing factors (e.g., absence of equipment, technology breakage, lack of training). Implants were commonly prohibitively expensive. Building basic orthopaedic care capacity at 15 hospitals without such capacity would improve spatial access to basic care from 74.9% to 83.0% of the population (uncertainty interval [UI] of 81.2% to 83.6%), providing access for an additional 2,169,714 Ghanaians.

Conclusions: The availability of several low-cost resources could be better supplied by improvements in organization and training for orthopaedic trauma care. There is a critical need to advocate and provide funding for orthopaedic resources. These initiatives might be particularly effective if aimed at hospitals that could provide care to a large proportion of the population.

Peer review: This article was reviewed by the Editor-in-Chief and one Deputy Editor, and it underwent blinded review by two or more outside experts. It was also reviewed by an expert in methodology and statistics. The Deputy Editor reviewed each revision of the article, and it underwent a final review by the Editor-in-Chief prior to publication. Final corrections and clarifications occurred during one or more exchanges between the author(s) and copyeditors.

Disclosure: This study was funded by grants R25-TW009345 and D43-TW007267 from the Fogarty International Center, U.S. National Institutes of Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. On the **Disclosure of Potential Conflicts of Interest** forms, which are provided with the online version of the article, one or more of the authors checked "yes" to indicate that the author received payment and/or services from a third party (government, commercial, private foundation, etc.) for an aspect of the submitted work.

Orthopaedic conditions incur more than 52 million disability-adjusted life years (DALYs) annually worldwide, comprising more than 16% of the global disease burden¹. This burden falls disproportionately on low and middle-income countries (LMICs), which are least equipped to provide orthopaedic care^{2,3}. The delivery of safe and timely care for orthopaedic conditions can prevent disability and minimize health-care costs by avoiding the complexity and expense associated with delayed treatment^{4,5}. Therefore, LMICs have the greatest need for accurate estimates of the burden of orthopaedic conditions, assessment of orthopaedic capacity, and targeted health-system strengthening interventions⁶.

The burden of orthopaedic trauma conditions in Ghana has been grossly defined. Injuries incur an estimated 2,772 DALYs per 100,000 people annually⁷. For reference, this is 44% more than the DALYs incurred from injury in Egypt and 30% more than in Canada⁷. Population-based studies of injury have reported 53 to 83 deaths per 100,000 people^{8,9}.

In 2014 through 2015, a national assessment of trauma care capacity in Ghana was performed¹⁰. We used a subset of data from that assessment to describe essential orthopaedic trauma care capacity countrywide¹¹. Additionally, we mapped population-level spatial access to orthopaedic trauma care and identified hospitals that would most improve access to care if their capacity was improved. The findings might inform health-system planning exercises.

Materials and Methods

Setting

Ghana is a heavily indebted LMIC in West Africa with a population of 26 million people and an annual per capita income of \$1,760 U.S.¹². Ghana has 10 regions that are divided into 216 districts. There are 4 tertiary hospitals, 9 referral hospitals, and 155 mission or government-run first-level hospitals¹³.

First-level hospitals are typically staffed by general medical officers (i.e., doctors with 2 years of house officer training) and nurse anesthetists, and have between 50 and 100 beds; some provide surgical services^{14,15}. Conditions requiring more complex care are referred to 1 of the referral or tertiary hospitals. Referral hospitals are typically staffed by 1 or more specialist provider(s) (e.g., general and/or orthopaedic surgeons) and contain between 100 and 400 beds. Each of the tertiary hospitals offers more specialized care.

Capacity Assessment

The Kwame Nkrumah University of Science and Technology in Ghana and the University of Washington in Seattle gave ethical approval for the study. A complete description of the methods used for the capacity assessment has been published previously¹⁰. Briefly, all tertiary and referral hospitals and a selection of first-level hospitals (totaling 40 facilities) were purposively sampled to represent hospitals most likely to care for injuries. At least 1 district-level hospital in each region was selected by being (1) in a populous area, near heavily-trafficked roads likely to produce road-traffic injuries; or (2) identified by the respective regional health directorate as caring for a higher injury volume than others within the region; or (3) designated as a trauma hospital; as well as being (4) outside of an hour's transport to a regional or tertiary hospital, to avoid hospitals that often get bypassed by those in need of trauma care.

We used a structured assessment tool adapted from the World Health Organization (WHO) *Guidelines for Essential Trauma Care* (GETC) that included 17 resources required for perioperative and musculoskeletal trauma care as proxies for overall orthopaedic trauma care capacity (e.g., radiography, image intensification, closed reduction, skeletal traction, external and internal fixation, and open fracture debridement)¹⁶.

We systematically interviewed each staff member performing the functions of the following positions at each sampled hospital (if the position was filled at the facility): surgeons, anesthetists, medical officers, administrators, accountants, procurement and logistic officers, technicians, biomedical engineers, and/or department in-charge nurses. Some hospitals did not have 1 or more of these positions (e.g., surgeon, logistics officer, or technician at a first-level hospital). Staff members rated item availability as 0 if it was absent but should be present; 1 if it was inadequate, available to less than half of those who need it; 2 if it was partially adequate, available to more than half, but not to all who need it; or 3 if it was adequate, present, and readily available to almost everyone in need and used when needed.

The median rating was used if there were disagreements on the same resource. For each resource rated 0 to 2, factors that contributed to deficiency were systematically explored. Direct inspection of items was performed to corroborate ratings and troubleshoot reasons for nonavailability. Direct inspection included visually determining if the item was present or absent, examining it for functional availability, and evaluating why it was not available at times if rated ≤ 2 (e.g., stock management practices, training deficiencies, and breakage). Item availability rating (median and range) and factors contributing to nonavailability (percent of hospitals reporting that factor for each item rated ≤ 2) were described.

Data for Mapping Spatial Access

The number and type of surgical procedures performed at first-level and referral hospitals countrywide are reported monthly to the Ministry of Health using the DHIS-2 platform (Health Information Systems Programme). The vast majority of hospitals are compliant with this mandate¹⁷. Smaller and more remote hospitals report data less reliably; these hospitals are also the least likely to provide any surgical care. Similar data from tertiary hospitals are not reported. Thus, orthopaedic trauma care capabilities at tertiary hospitals were determined by site visits during the capacity assessment.

Using these data from 2014 and 2015, hospitals were sorted into 3 groups: hospitals that performed basic orthopaedic trauma care (i.e., nonoperative care, including closed reduction and skeletal traction, as well as debridement of open fracture), hospitals that performed intermediate orthopaedic care (i.e., external fixation and internal fixation), and hospitals that performed advanced orthopaedic care (i.e., complex long-bone and articular fracture management, and spine, pelvis, and hand surgery).

GIS (Geographic Information System) Data Management

Hospitals were geolocated using Google Earth. National population data were represented by a 100-m²-gridded population surface generated by the WorldPop Project, which was created using the 2010 census adjusted to 2015 estimates with the United Nations population projections¹⁸.

We created a national road network by combining primary and secondary road data from OpenStreetMap (OSM; Open Street Map Foundation), and tertiary road data from the Centre for Remote Sensing and Geographic Information Services (CERSGIS)^{19,20}. Following topological verification, travel speed was assigned to each class of road based on national traffic laws: 100, 50, and 30 km/hr for primary, secondary, and tertiary roads, respectively^{21,22}.

Spatial Access to Orthopaedic Trauma Care

Cost-distance analyses were performed to determine population-level spatial access to each level of orthopaedic trauma care^{23,24}. The cost surface was constructed by superimposing the road network and corresponding speed limit over the country. Background cells were assigned a value of 5 km/hr (i.e., walking speed). The value of each cell represented the time required to traverse that cell. The proportion of the population with spatial access to care was evaluated by overlaying the gridded population surface over the cost surface and calculating the proportion of the population within 60 and 120 minutes of a hospital capable of providing orthopaedic care. To evaluate model stability, 2 additional cost surfaces were built where travel speed for each road segment was augmented by $\pm 20\%$ (i.e., uncertainty interval [UI]).

Location-Allocation Model

Three location-allocation models were built to identify the facilities with the greatest impact on population-level spatial access to each level of orthopaedic trauma care^{25,26}. The analyses used lists of candidate facilities to identify 15, 10, and 2 additional hospitals to provide basic, intermediate, and advanced orthopaedic care, respectively. Each candidate list represented the hospitals that would require the lowest resource investment to attain a higher level of orthopaedic care. Basic facilities were chosen from a list of facilities already providing some trauma care in Ghana, but not full basic orthopaedic care (e.g., splinting, but not closed reduction or traction); intermediate facilities were chosen from the same list plus facilities already providing basic orthopaedic care; and advanced facilities were chosen from a list of facilities currently providing intermediate orthopaedic care.

The population-weighted geographic centroid of each district represented demand points in the model. After combining the existing and expanded facilities, repeat cost-distance analyses were performed to quantify improvements in population-level spatial access following the simulated capability expansions.

Results

Capacity Assessment

In total, 29 first-level, 8 referral, and 3 tertiary hospitals were assessed (Table 1). Overall, pulse oximetry, blood transfusion capabilities, hemoglobin determination, radiograph capabilities,

and basic general surgery were relatively reliably available at all 3 levels of care (i.e., first-level, referral, and tertiary hospitals). Major general surgery, closed reduction of fractures, and image intensification were rarely available at the first-level hospitals, but reliably available at larger hospitals. Vascular repair, skin-grafting, external fixation of fractures, and spinal fixation were rarely available outside of tertiary hospitals.

Orthopaedic trauma care capacity was generally low and variable between and within hospital levels. Spinal immobilization was rarely performed at any hospital level despite its low cost (median rating of 1 at tertiary hospitals; range, 0 to 3). Radiograph capabilities had a median rating of 2 at all levels (range, 0 to 3 at both first-level and referral hospitals). Portable radiograph machines were rarely available, even at tertiary hospitals (median rating of 1 at tertiary hospitals; range, 0 to 3). Conversely, image intensification was reliably available at all of the tertiary hospitals (median rating of 3; range, 3 to 3).

While closed reduction of fractures had a median rating of 2 at first-level hospitals and a median rating of 3 at referral hospitals, its availability varied markedly within both levels (range, 0 to 3). Orthopaedic procedures were

TABLE 1 Median Availability Ratings and Ranges of Orthopaedic Care Items and Services at Hospitals in Ghana

Orthopaedic Care Items and Services	Median Item Availability Rating (Range)*		
	First-Level Hospital	Referral Hospital	Tertiary Hospital
Number assessed	29	8	3
Pulse oximetry	3 (0-3)	2 (2-3)	3 (3-3)
Blood transfusion capabilities	2 (1-3)	2 (1-3)	2 (2-3)
Hemoglobin determination	3 (1-3)	3 (2-3)	3 (3-3)
Radiograph capabilities	2 (0-3)	2 (0-3)	2 (2-3)
Portable radiograph machines	0 (0-3)	0 (0-1)	1 (0-3)
Basic general surgery†	3 (0-3)	3 (0-3)	3 (3-3)
Major general surgery‡	1 (0-3)	3 (0-3)	3 (3-3)
Vascular repair	0 (0-2)	0 (0-2)	2 (0-2)
Skin-grafting	0 (0-3)	0 (0-2)	2 (1-3)
Closed reduction	2 (0-3)	3 (0-3)	3 (3-3)
Skeletal traction	0 (0-3)	1.5 (0-3)	3 (3-3)
External fixation	0 (0-3)	0 (0-3)	3 (3-3)
Internal fixation§	N/A	0 (0-1)	1 (1-2)
Prosthetics for amputees	0 (0-3)	0	0 (0-1)
Image intensification	0 (0-3)	1 (1-2)	3 (3-3)
Spine immobilization#	0 (0-3)	0 (0-1)	1 (0-3)
Spinal fixation	N/A	0	3 (0-3)

*Item availability was rated by hospital staff: 0 = absent but should be present; 1 = inadequate, available to less than half of those who need it; 2 = partially adequate, available to more than half, but not to all who need it; or 3 = adequate, present, and readily available to almost everyone in need and used when needed. †Basic general surgery = wound debridement, 1% total body surface area burn excision, digital amputation, surgical airway, and debridement of open fracture. ‡Major general surgery = neck exploration, exploratory laparotomy, major amputation, as well as basic neurosurgery (burr hole, treatment of open depressed skull fracture). §Internal fixation = Kirschner wires, plate and screws, and intramedullary nails. #Spine immobilization = cervical collar and back board. N/A = not applicable (a first-level hospital would not have these orthopaedic care items and services available).

TABLE II Percentage of Hospitals Reporting Factors Contributing to Specific Item Nonavailability in Ghana*

	Resource Absence (%)	Broken Equipment (%)	Personnel Shortage (%)	Lack of Training (%)	Lack of Reagents, Supplies (%)	Out of stock, Insufficient Quantity (%)	User Fees Necessary (%)
First-level hospitals							
Pulse oximetry	7	21				24	
Hemoglobin		14			24		
Radiographs	24	45	14	4		10	
Basic general surgery†	4		7	35			
Skin or skeletal traction	72			28			
Spine immobilization‡	55					31	
Referral and tertiary hospitals							
Pulse oximetry		27				36	
Hemoglobin		18	9				
Radiographs	9	46	27			9	9
Major general surgery§			9	9			
External fixation	46			36		9	9
Internal fixation#	46			9			45
Image intensification	36	18	10	36			
Prosthetics for amputees	91						9

*Contributing factors to item nonavailability were systematically captured for all items rated ≤ 2 . Factors were not considered mutually exclusive except when items had never been present at a facility; therefore, some lines sum to $>100\%$. †Basic general surgery = wound debridement, 1% total body surface area burn excision, digital amputation, surgical airway, and debridement of open fracture. ‡Spine immobilization = cervical collar and back board. §Major general surgery = neck exploration, exploratory laparotomy, and major amputation, as well as basic neurosurgery (burr hole, treatment of open depressed skull fracture). #Internal fixation = Kirschner wires, plate and screws, and intramedullary nails.

rarely available at first-level hospitals (median rating of 0 for both traction and external fixation; range, 0 to 3). Similarly, external fixation and internal fixation had low availability ratings at referral hospitals (median rating of 0). Internal fixation was often not available at tertiary hospitals (median rating of 1; range, 1 to 2). Although available at some tertiary facilities, spinal fixation capacity varied within the tertiary level (median rating of 3; range, 0 to 3). Prosthetics for amputees were rarely available at any level (median rating of 0 at all levels).

Factors Contributing to Low Capacity

Resource absence (i.e., having never been present at a facility) was the most commonly reported factor that contributed to deficiency (Table II). However, long periods of broken equipment, lack of training, and poor supply chain management practices (e.g., lack of reagents and other supplies as well as out-of-stock equipment and insufficient quantity) often led to resource deficiency. User fees were prohibitively expensive for internal fixation at 45% of referral and tertiary hospitals.

Population-Level Spatial Access to Orthopaedic Trauma Care

Just over half of Ghanaians can reach a facility capable of providing basic orthopaedic care within 1 hour from their

home (57.8%; UI of 52.6% to 62.9%) and 74.1% can reach a facility within 2 hours (UI of 70.8% to 77.3%) (Table III). Intermediate orthopaedic care is mainly provided at the same facilities that perform basic care; thus, the percent of the population with spatial access to intermediate care is similar. Around one-third of the population has spatial access to advanced care within 1 hour (35.3%; UI of 30.8% to 39.7%); 59.2% of the population can access advanced care within 2 hours (UI of 50.0% to 68.3%).

Hospitals Targeted for Orthopaedic Trauma Care Capability Improvements

The increase in potential spatial access to orthopaedic care following the inclusion of the hospitals identified by the location-allocation models for targeted capability improvements is illustrated in Figure 1 and described in Table III. Building basic orthopaedic care capacity at 15 hospitals would improve 2-hour spatial access to basic care from 74.9% to 82.4% of the population (UI of 81.2% to 83.6%; 2,169,714 additional Ghanaians). Similarly, 2-hour spatial access to intermediate care would improve from 74.6% to 80.8% of the population (UI of 78.9% to 82.7%; 1,875,062 additional Ghanaians) if this level of care was developed at 10 targeted hospitals. Finally, providing advanced orthopaedic care at 2 additional hospitals would increase 2-hour spatial access from 59.4% to 66.6% of the population (UI of 59.6% to 73.6%; 2,357,221 additional Ghanaians).

TABLE III Current and Potential Population-Level Spatial Access to Orthopaedic Care in Ghana

Orthopaedic Care Capacity	Before Capacity Improvement				After Capacity Improvement	
	Within 1 Hour		Within 2 Hours		Within 2 Hours	
	Population Access (% of population)	Uncertainty Interval (%)	Population Access (% of population)	Uncertainty Interval (%)	Population Access* (% of population)	Uncertainty Interval (%)
Basic†	57.8	52.6-62.9	74.1	70.8-77.3	82.4	81.2-83.6
Intermediate‡	54.3	48.0-60.6	73.5	69.8-77.1	80.8	78.9-82.7
Advanced§	35.3	30.8-39.7	59.2	50.0-68.3	66.6	59.6-73.6

*The location-allocation models identified 15 hospitals with basic orthopaedic care capacity, 10 hospitals with intermediate orthopaedic care capacity, and 2 hospitals with advanced capacity that would most improve spatial access to orthopaedic care if strengthened from a candidate list of all hospitals that performed no, basic, and intermediate orthopaedic care, respectively. †Basic orthopaedic care capacity = nonoperative care, including closed reduction, skeletal traction, and debridement of open fracture. ‡Intermediate orthopaedic care capacity = external fixation and internal fixation. §Advanced orthopaedic care capacity = complex long-bone and articular fracture management, and spine, pelvis, and hand surgery.

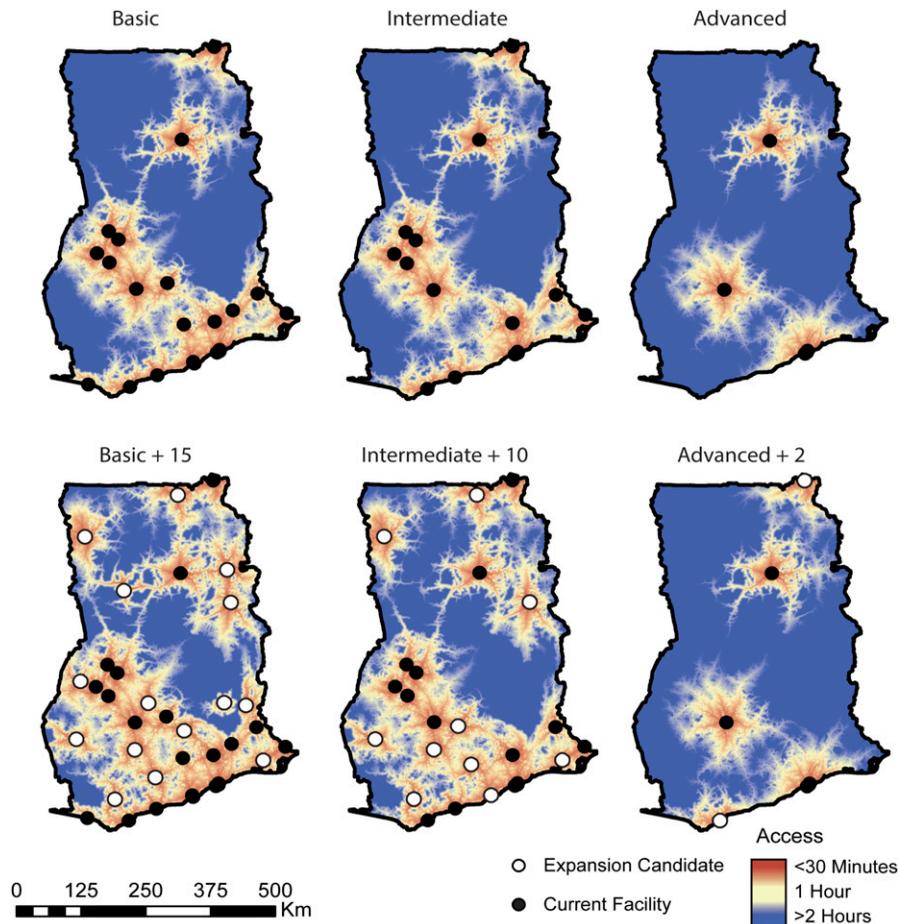


Fig. 1 Population-level spatial access to orthopaedic care and candidates for orthopaedic care capacity expansion in Ghana. Basic orthopaedic care capacity is nonoperative care, including closed reduction and skeletal traction, as well as debridement of open fracture. Intermediate orthopaedic care capacity is external fixation and internal fixation. Advanced orthopaedic care capacity is complex long-bone and articular fracture management, as well as spine, pelvis, and hand surgery. The location-allocation models identified 15, 10, and 2 facilities that would most improve spatial access to orthopaedic care if strengthened from a candidate list of all hospitals that performed no, basic, and intermediate orthopaedic care, respectively.

Discussion

This study assessed orthopaedic trauma care capacity country-wide throughout Ghana, mapped population-level spatial access to orthopaedic care, and identified hospitals that would most improve access to care if capacity was improved. We documented widespread deficiencies in orthopaedic trauma care capacity, particularly for radiography and procedural care (e.g., skeletal traction, external fixation, debridement of open fracture). Several factors contributed to orthopaedic trauma care resource deficiencies: resource absence (i.e., never present at the hospital before), broken equipment, lack of training, and prohibitively expensive user fees. Currently, >40% of the population cannot access orthopaedic trauma care within 1 hour, and 25% cannot access care within 2 hours. We identified hospitals that would most improve access to care if orthopaedic trauma capacity was strengthened.

Surgical care capacity assessments from LMICs have consistently reported inadequate orthopaedic care capacity. A similar assessment of 56 first-level and 29 large hospitals (i.e., referral and tertiary hospitals) was performed in Nepal²⁷. At first-level hospitals, the mean rating for spine immobilization, radiography, closed reduction, and external fixation was 0 at the facilities. Even at large hospitals, closed reduction, traction, and external fixation were not reliably available. Prosthetics had a mean rating of 0. In Sierra Leone, an orthopaedic care capacity assessment reported that only 3 of the 10 assessed hospitals could care for an open fracture or perform an amputation if needed²⁸. These examples demonstrate that LMICs urgently need orthopaedic capacity improvement to avert preventable death and disability from the growing burden of injury and other musculoskeletal conditions.

A similar capacity assessment also was performed in Ghana in 2004²⁹. Comparing the assessment described herein to the initial assessment in 2004, the availability rating of many trauma care resources improved: pulse oximetry increased from 0 to 3, basic general surgery increased from 1 to 3, and major general surgery increased from 0 to 1 at the first-level hospitals³⁰. However, most resources for orthopaedic trauma care did not improve or were less available: external fixation did not improve at any hospital level, radiograph capabilities and internal fixation did not improve at referral or tertiary hospitals, portable radiograph machines decreased at all hospital levels (rating 2 to 1 or 1 to 0), and skeletal traction decreased from 1 to 0 at first-level hospitals. While improvements in general trauma care are laudable, the lack of improvements in orthopaedic care capacity calls for urgent attention.

Trained staff performing manipulation and casting can treat stable fractures inexpensively^{4,31,32}. However, unstable fractures typically require some form of fixation. Patients are often responsible for purchasing implants in Ghana, as in other LMICs³². As a result, casting or traction is commonly employed in the management of unstable lower-extremity fractures. Therefore, many fractures are undertreated and incur preventable disability. A recent cost analysis from Kenya demonstrated that surgical fixation was less expensive, associated with equivalent complications, and produced better functional outcomes

than traction³³. Studies from Uganda and Cambodia have demonstrated both the feasibility and cost-effectiveness of treating long-bone fractures with the Surgical Implant Generation Network (SIGN) intramedullary nail system without the need for image intensifiers, fracture tables, or power-reaming^{4,34}. Outcomes of SIGN intramedullary nailing from over 34,000 patients in 55 LMICs have shown better outcomes than current local standards of care and acceptably low complication rates³⁵. However, it should be noted that only 18% of patients who received a SIGN intramedullary nail had follow-up data for analysis in the aforementioned study. Prioritizing affordable access to hardware may result in fewer costs to the health-care system and less productivity losses for patients as a result of improved functional outcomes in the long run. The orthopaedic community must advocate for representation in the global health dialogue and dedicated funding for orthopaedic capacity improvements in LMICs given the potential to effectively reduce a large burden of disease^{36,37}.

Several limitations require consideration while interpreting these results. First, the rating scheme was somewhat subjective. To strengthen its validity, key informants from multiple departments that interacted with the same resource (e.g., radiography, emergency room doctors, emergency room nurses, surgeons, nurse anesthetists, radiograph technicians, and biomedical engineers) were asked about its availability to triangulate responses. Additionally, direct observation of equipment and supplies was performed. We did not systematically assess the availability of care for musculoskeletal infections or congenital, degenerative, oncologic, or sports medicine conditions. However, the lack of availability of basic resources required for essential orthopaedic care as defined by the World Bank is concerning, and demands redress prior to or in tandem with capacity improvements for the care of other musculoskeletal conditions¹¹. Lastly, the use of only population-level spatial access gaps to target hospitals for improvement neglects other important considerations, such as reducing nonspatial barriers to orthopaedic care (e.g., affordability and acceptability), prioritizing health equity (e.g., improving access to care for particularly marginalized or high-risk populations), and matching care availability with the geospatial distribution of disease^{38,39}. Despite the aforementioned limitations, these findings allow us to make reasonable conclusions about orthopaedic trauma care capacity, population-level spatial access to orthopaedic care in Ghana, and ways that they might be improved.

In conclusion, these findings demonstrate critical deficiencies in orthopaedic trauma care capacity and the resultant impact on population-level spatial access to care in Ghana. Although orthopaedic care should be funded and organized across the health-care system, we have identified facilities with the greatest impact on spatial access to orthopaedic care as rational targets for capacity-building interventions, such as training and making hardware available or subsidized. Access to care also can be improved by establishing protocols for the early recognition, stabilization, and timely transfer of patients with complex conditions

to facilities capable of definitive care. Importantly, orthopaedic care capacity improvements must occur in parallel with training and quality-assurance initiatives to have the greatest impact on well-being and population health. While these data are particularly useful for Ghana, this study might also serve as a model for other countries that are in need of or planning strategic orthopaedic care capacity improvements. ■

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References

- Collaborators GBD: GBD 2013 Mortality and Causes of Death Collaborators. Global, regional, and national age-sex specific all-cause and cause-specific mortality for 240 causes of death, 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet*. 2015 Jan 10;385(9963):117-71. Epub 2014 Dec 18.
- Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, Aboyans V, Abraham J, Adair T, Aggarwal R, Ahn SY, Alvarado M, Anderson HR, Anderson LM, Andrews KG, Atkinson C, Baddour LM, Barker-Collo S, Bartels DH, Bell ML, Benjamin EJ, Bennett D, Bhalla K, Bikbov B, Bin Abdulhak A, Birbeck G, Blyth F, Bolliger I, Boufous S, Bucello C, Burch M, Burney P, Carapetis J, Chen H, Chou D, Chugh SS, Coffeng LE, Colan SD, Colquhoun S, Colson KE, Condon J, Connor MD, Cooper LT, Corriere M, Cortinovis M, de Vaccaro KC, Couser W, Cowie BC, Criqui MH, Cross M, Dabhadkar KC, Dahodwala N, De Leo D, Degenhardt L, Delossantos A, Denenberg J, Des Jarlais DC, Dharmaratne SD, Dorsey ER, Driscoll T, Duber H, Ebel B, Erwin PJ, Espindola P, Ezzati M, Feigin V, Flaxman AD, Forouzanfar MH, Fowkes FG, Franklin R, Fransen M, Freeman MK, Gabriel SE, Gakidou E, Gaspari F, Gillum RF, Gonzalez-Medina D, Halasa YA, Haring D, Harrison JE, Havmoeller R, Hay RJ, Hoen B, Hotez PJ, Hoy D, Jacobsen KH, James SL, Jasrasaria R, Jayaraman S, Johns N, Karthikeyan G, Kassebaum N, Keren A, Khoo JP, Knowlton LM, Kobusingye O, Koranteng A, Krishnamurthi R, Lipnick M, Lipshultz SE, Ohno SL, Mabweijano J, MacIntyre MF, Mallinger L, March L, Marks GB, Marks R, Matsumori A, Matzopoulos R, Mayosi BM, McAnulty JH, McDermott MM, McGrath J, Mensah GA, Merriman TR, Michaud C, Miller M, Miller TR, Mock C, Mocumbi AO, Mokdad AA, Moran A, Mulholland K, Nair MN, Naldi L, Narayan KM, Nasseri K, Norman P, O'Donnell M, Omer SB, Ortblad K, Osborne R, Ozgediz D, Pahari B, Pandian JD, Rivero AP, Padilla RP, Perez-Ruiz F, Perico N, Phillips D, Pierce K, Pope CA 3rd, Porrini E, Pourmalek F, Raju M, Ranganathan D, Rehm JT, Rein DB, Remuzzi G, Rivara FP, Roberts T, De León FR, Rosenfeld LC, Rushton L, Sacco RL, Salomon JA, Sampson U, Sanman E, Schwebel DC, Segui-Gomez M, Shepard DS, Singh D, Singleton J, Sliwa K, Smith E, Steer A, Taylor JA, Thomas B, Tleyeh IM, Towbin JA, Truelsen T, Undurraga EA, Venketasubramanian N, Vijayakumar L, Vos T, Wagner GR, Wang M, Wang W, Watt K, Weinstock MA, Weintraub R, Wilkinson JD, Woolf AD, Wulf S, Yeh PH, Yip P, Zabetian A, Zheng ZJ, Lopez AD, Murray CJ, AlMazroa MA, Memish ZA. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012 Dec 15;380(9859):2095-128.
- Groen RS, Samai M, Stewart KA, Cassidy LD, Kamara TB, Yambasu SE, Kingham TP, Kushner AL. Untreated surgical conditions in Sierra Leone: a cluster randomised, cross-sectional, countrywide survey. *Lancet*. 2012 Sep 22;380(9847):1082-7. Epub 2012 Aug 14.
- Gosselin RA, Heitto M, Zirkle L. Cost-effectiveness of replacing skeletal traction by interlocked intramedullary nailing for femoral shaft fractures in a provincial trauma hospital in Cambodia. *Int Orthop*. 2009 Oct;33(5):1445-8. Epub 2009 May 13.
- Ariès MJ, Joosten H, Wegdam HH, van der Geest S. Fracture treatment by bonesetters in central Ghana: patients explain their choices and experiences. *Trop Med Int Health*. 2007 Apr;12(4):564-74.
- World Health Organization; Mock C, Julliard C, Brundage S, Goosen J, Joshipura M. Guidelines for trauma quality improvement programmes. 2009. http://apps.who.int/iris/bitstream/10665/44061/1/9789241597746_eng.pdf. Accessed 2016 May 2.
- Institute of Health Metrics and Evaluation. Data visualizations. Global burden of disease cause patterns. 2013. <https://vizhub.healthdata.org/gbd-compare/>. Accessed 2015 May 27.
- Mock CN, Abantanga F, Cummings P, Koepsell TD. Incidence and outcome of injury in Ghana: a community-based survey. *Bull World Health Organ*. 1999;77(12):955-64.
- Gyedu A, Nakua EK, Otupiri E, Mock C, Donkor P, Ebel B. Incidence, characteristics and risk factors for household and neighborhood injury among young children in semiurban Ghana: a population-based household survey. *Inj Prev*. 2015 Apr;21(e1):e71-9.
- Stewart BT, Quansah R, Gyedu A, Ankomah J, Donkor P, Mock C. Strategic assessment of trauma care capacity in Ghana. *World J Surg*. 2015 Oct;39(10):2428-40.
- Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT; DCP3 Essential Surgery Author Group. Essential surgery: key messages from Disease Control Priorities, 3rd edition. *Lancet*. 2015 May 30;385(9983):2209-19. Epub 2015 Feb 5.
- CIA world factbook – the best country factbook available online. United States of America Central Intelligence Agency. <http://www.cia-worldfactbook.us/africa/ghana.html>. Accessed 2015 Apr 12.
- Ghana health sector. Accra, Ghana: Ghana Health Service, 2010. http://www.ghanahelthservice.org/downloads/GHS_2010_Annual%20Report_Final.pdf.
- Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, Fleischer-Djoleto C, Moresky R, McCord CW, Cherian M, Abdullah F. Assessment of capacity for surgery, obstetrics and anaesthesia in 17 Ghanaian hospitals using a WHO assessment tool. *Trop Med Int Health*. 2010 Sep;15(9):1109-15. Epub 2010 Jul 14.
- Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, McCord CW, Abdullah F. Surgical training and experience of medical officers in Ghana's district hospitals. *Acad Med*. 2011 Apr;86(4):529-33.
- World Health Organization; Mock C, Lormand J, Goosen J, Joshipura M, Peden M. Guidelines for essential trauma care. 2004. http://www.who.int/violence_injury_prevention/publications/services/en/guidelines_traumacare.pdf. Accessed 2016 May 2.
- Achampong EK. The state of information and communication technology and health informatics in Ghana. *Online J Public Health Inform*. 2012;4(2). Epub 2012 Sep 14.
- WorldPop. 2015. <http://www.worldpop.org.uk>. Accessed 2015 Jul 30.
- OpenStreetMap. 2015. <http://www.openstreetmap.org>. Accessed 2015 Jul 30.
- Centre for Remote Sensing and Geographic Information Services. 2015. <http://cersgis.org/home.html>. Accessed 2015 Jul 30.
- Damsere-Derry J, Afukaar FK, Donkor P, Mock C. Assessment of vehicle speeds on different categories of roadways in Ghana. *Int J Inj Contr Saf Promot*. 2008 Jun;15(2):83-91.

- 22.** Derry JD, Afukaar FK, Donkor P, Mock C. Study of vehicle speeds on a major highway in Ghana: implication for monitoring and control. *Traffic Inj Prev.* 2007 Jun;8(2):142-6.
- 23.** Delamater PL, Messina JP, Shortridge AM, Grady SC. Measuring geographic access to health care: raster and network-based methods. *Int J Health Geogr.* 2012;11(1):15. Epub 2012 May 15.
- 24.** Huerta Munoz U, Källestål C. Geographical accessibility and spatial coverage modeling of the primary health care network in the Western Province of Rwanda. *Int J Health Geogr.* 2012;11:40. Epub 2012 Sep 17.
- 25.** Polo G, Acosta CM, Ferreira F, Dias RA. Location-allocation and accessibility models for improving the spatial planning of public health services. *PLoS One.* 2015;10(3):e0119190. Epub 2015 Mar 16.
- 26.** Yang DH, Goerge R, Mullner R. Comparing GIS-based methods of measuring spatial accessibility to health services. *J Med Syst.* 2006 Feb;30(1):23-32.
- 27.** Shah MT, Bhattarai S, Lamichhane N, Joshi A, LaBarre P, Joshipura M, Mock C. Assessment of the availability of technology for trauma care in Nepal. *Injury.* 2015 Sep;46(9):1712-9. Epub 2015 Jun 16.
- 28.** Groen RS, Kamara TB, Dixon-Cole R, Kwon S, Kingham TP, Kushner AL. A tool and index to assess surgical capacity in low income countries: an initial implementation in Sierra Leone. *World J Surg.* 2012 Aug;36(8):1970-7.
- 29.** Quansah R, Mock C, Abantanga F. Status of trauma care in Ghana. *Ghana Med J.* 2004;38(4):149-52.
- 30.** Stewart BT, Quansah R, Gyedu A, Boakye G, Abantanga F, Ankomah J, Donkor P, Mock C. Serial assessment of trauma care capacity in Ghana in 2004 and 2014. *JAMA Surg.* 2016 Feb 1;151(2):164-71.
- 31.** Cotton M, Henry JA, Hasek L. Value innovation: an important aspect of global surgical care. *Global Health.* 2014;10:1. Epub 2014 Jan 6.
- 32.** Zirkle LG Jr. Injuries in developing countries—how can we help? The role of orthopaedic surgeons. *Clin Orthop Relat Res.* 2008 Oct;466(10):2443-50. Epub 2008 Aug 7.
- 33.** Opondo E, Wanzala P, Makokha A. Cost effectiveness of using surgery versus skeletal traction in management of femoral shaft fractures at Thika level 5 hospital, Kenya. *Pan Afr Med J.* 2013;15:42. Epub 2013 Jun 6.
- 34.** Phillips J, Zirkle LG, Gosselin RA. Achieving locked intramedullary fixation of long bone fractures: technology for the developing world. *Int Orthop.* 2012 Oct;36(10):2007-13. Epub 2012 Jul 31.
- 35.** Young S, Lie SA, Hallan G, Zirkle LG, Engesaeter LB, Havelin LI. Low infection rates after 34,361 intramedullary nail operations in 55 low- and middle-income countries: validation of the Surgical Implant Generation Network (SIGN) online surgical database. *Acta Orthop.* 2011 Dec;82(6):737-43. Epub 2011 Nov 9.
- 36.** LeBrun DG, Chackungal S, Chao TE, Knowlton LM, Linden AF, Notrica MR, Solis CV, McQueen KA. Prioritizing essential surgery and safe anesthesia for the Post-2015 Development Agenda: operative capacities of 78 district hospitals in 7 low- and middle-income countries. *Surgery.* 2014 Mar;155(3):365-73. Epub 2013 Oct 11.
- 37.** Patel PB, Hoyler M, Maine R, Hughes CD, Hagander L, Meara JG. An opportunity for diagonal development in global surgery: cleft lip and palate care in resource-limited settings. *Plast Surg Int.* 2012;2012:892437. Epub 2012 Dec 20.
- 38.** Stewart BT, Gyedu A, Abantanga F, Abdulai AR, Boakye G, Kushner A. Barriers to essential surgical care in low- and middle-income countries: a pilot study of a comprehensive assessment tool in Ghana. *World J Surg.* 2015 Nov;39(11):2613-21.
- 39.** Asante AD, Zwi AB, Ho MT. Equity in resource allocation for health: a comparative study of the Ashanti and Northern Regions of Ghana. *Health Policy.* 2006 Oct;78(2-3):135-48. Epub 2006 May 15.

APPENDIX 88 - STRATEGIC ASSESSMENT OF THE
AVAILABILITY OF PEDIATRIC TRAUMA CARE EQUIPMENT,
TECHNOLOGY AND SUPPLIES IN GHANA



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Strategic assessment of the availability of pediatric trauma care equipment, technology and supplies in Ghana

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Abstract

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Conflict of interest statement

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Background—This study aimed to assess the availability of pediatric trauma care items (i.e. equipment, supplies, technology) and factors contributing to deficiencies in Ghana.

Methods—Ten universal and 9 pediatric-sized items were selected from the World Health Organization's *Guidelines for Essential Trauma Care*. Direct inspection and structured interviews with administrative, clinical and biomedical engineering staff were used to assess item availability at 40 purposively sampled district, regional and tertiary hospitals in Ghana.

Results—Hospital assessments demonstrated marked deficiencies for a number of essential items (e.g. basic airway supplies, chest tubes, blood pressure cuffs, electrolyte determination, portable Xray). Lack of pediatric-sized items resulting from equipment absence, lack of training, frequent stock-outs and technology breakage were common. Pediatric items were consistently less available than adult-sized items at each hospital level.

Conclusion—This study identified several successes and problems with pediatric trauma care item availability in Ghana. Item availability could be improved, both affordably and reliably, by better organization and planning (e.g. regular assessment of demand and inventory, reliable financing for essential trauma care items). In addition, technology items were often broken. Developing local service and biomedical engineering capability was highlighted as a priority to avoid long periods of equipment breakage.

Keywords

trauma; pediatric; capacity; operations management; developing country; global surgery

Introduction

Trauma accounts for more than 25% of pediatric deaths and even more disability worldwide. [1] After infancy, injuries are responsible for more deaths than malaria, neglected tropical diseases and malnutrition combined in sub-Saharan Africa.[1] However, funding for injury prevention, treatment and rehabilitation capacity improvement accounts for less than 1% of international financial assistance to low- and middle-income countries (LMICs).[2] Investment in trauma care capacity is urgently needed to reduce this burden.[3]

However, planning and organizing trauma care can substantially reduce disability and preventable deaths as well.[4-7] Mandatory for successful trauma systems is reliable and timely availability of equipment, supplies and appropriately trained personnel.[8] To define minimum standards for necessary injury care resources the World Health Organization (WHO) published *Guidelines for Essential Trauma Care* (GETC).

More than twenty national assessments of surgical and trauma care capacity in LMICs have been performed using GETC and similar assessment tools.[9-18] These assessments reported critical deficiencies in infrastructure, equipment and supplies. Though most of these assessments have not specifically addressed pediatric trauma and surgical capacity, they have been important for establishing a case for advocacy and providing baseline data from which capacity improvements can be benchmarked. Nonetheless, caring for injured children requires reliable stock of pediatric-sized non-drug consumables and familiarity with the unique aspects of pediatric surgical care.

Until recently, assessments have not focused on the factors contributing to item deficiencies; and therefore, have not been able to identify targets for capacity improvement interventions. Shah et al performed an assessment of trauma care technology availability in Gujarat State, India.[14] A lack of numerous specific items, many of which were low cost, due to stock outs and equipment breakdowns was common. Moreover, there was a mismatch of equipment and trained personnel. However, locally manufactured items were fairly well supplied. The authors advocated for better procurement and stock-management, optimizing training for use of existing resources, and strengthening service contracts and local repair capabilities. Similar deficiency cause analyses, useful for planning targeted health systems strengthening interventions, have not been done in other LMICs.

This study aimed to assess the availability of pediatric trauma care items (i.e. equipment, supplies, technology) in district-level, regional and tertiary hospitals in Ghana. It also sought to identify factors contributing to these deficiencies, as well as good availability. By doing so, potential solutions to inefficient aspects of health systems management and maladapted equipment and technology for trauma care could be identified.

Methods

Setting

Ghana is a lower-middle income country in West Africa with a population of 26 million people and an annual per capita income of US\$ 1,760.[19] Ghana has 10 regions divided into 110 districts. Most districts have several primary health centers (PHC) and a government or mission hospital that serves as a district (first-level) hospital. PHCs provide only basic public health and primary care services; therefore, they were not included in the study. District-level hospitals are staffed by medical officers and nurse anesthetists, usually offer general and very basic pediatric surgical services and have between 50 – 100 beds.[20] In addition to medical officers and nurse anesthetists, regional hospitals are often staffed by specialist providers (pediatricians, general and orthopedic surgeons) and contain between 100 – 400 beds. Though surgical services offered at regional hospitals are broader in scope, advanced pediatric surgical care is not provided. There are four tertiary care hospitals in Ghana (one of which doubles as a regional hospital); all are affiliated with a medical school or residency program and offer specialist pediatric surgical care.[21]

Sampling— All regional and tertiary facilities and a selection of district-level hospitals (totaling 40 facilities) were purposively sampled to represent hospitals most likely to care for injuries, the diversity of trauma care development, geography and local socioeconomics. Permission and assistance in selecting hospitals using the aforementioned criteria was sought from each regional health directorate prior to hospital surveys. At least one district-level hospital in each region was selected by being:

- In a populous area, near heavily-trafficked roads likely to produce traffic injuries;
or
- Identified by the respective regional health directorate as caring for a higher injury volume than others within the region; *or*

- Designated as a trauma hospital; *and*
- Outside of an hour's transport to a regional or tertiary hospital.

One regional and one tertiary hospital declined participation.

Data collection—The WHO GETC lists 260 items of personnel and physical resources *essential or desirable* at different levels within a healthcare system. Although items posed by the WHO GETC are generic with regards to patient size or age, amendments have been made to the recommendations to make them specific to pediatric trauma care. In addition, the WHO GETC recommends that pediatric-sized items be present at the same hospital level as one would expect for adult-sized items. This study examined 9 pediatric-sized items for pediatric trauma resuscitation (e.g. airway supplies, IV catheters, cervical collars), in addition to 10 universal items from the parent study (e.g. electronic cardiac monitoring, blood transfusion capabilities, stationary Xray).[22] Technology items were defined as electronic medical equipment (e.g. pulse oximetry, Xray). The parent study examined 32 items from the WHO GETC, including both *essential* and *desirable* items; the study focused on adult trauma care item availability and included a root causes analysis of item deficiencies.[22]

After leadership approval at each facility, one or more of the following (depending on the local context) were asked to complete their respective part of the survey: surgeons, anesthetists, medical officers, professionals, technicians and/or in-charge nurses from the casualty, theatre, critical care, laboratory, radiology, physiotherapy, procurement, accounts and engineering departments. Item availability was rated as:

- 0 – Absent but should be present;
- 1 – Inadequate, available to less than half of those who need it;
- 2 – Partially adequate, available to more than half, but not to most who need it; or
- 3 – Adequate, present and readily available to almost everyone in need and used when needed.

For items rated 0 - 2, contributing factors were systematically asked and not considered mutually exclusive (except when items had never been present at a facility). These were, 'The item or service has/is:

- Never been present;
- Present but broken and awaiting repairs;
- Present and staff able to use it, but when they go home at night or on the weekend no one is available to fill the position;
- No staff member trained in using the available item;
- Available, but lacks reagents or supplies;
- Necessary equipment or supplies out of stock or insufficient in number;

- Available, but only after pre-payment that prevents many from receiving the service or item; and/or
- Other, with explanation.’

Direct inspection of items was performed to corroborate ratings and further troubleshoot reason(s) for non-availability. By doing so, deficiencies related to ineffective healthcare system management practices, personnel or training deficiencies, and insufficient financing mechanisms could be identified.

Data collection and analysis—Data were collected on paper forms and transcribed to Microsoft Excel (Redmond, Washington). Item availability rating (median and range) and factors contributing to non-availability (percent of hospitals reporting that factor) were described using Stata v13 (College Station, Texas). Wilcoxon signed-rank test was used to determine if there was a difference in pediatric and adult trauma care item availability at each hospital level.

Ethics—The Kwame Nkrumah University of Science and Technology and Komfo Anokye Teaching Hospital Committee for Human Research and Publication Ethics and the University of Washington Institutional Review Board gave approval for the study. In addition, the Chief Director of the Ghana Ministry of Health, Director General of the Ghana Health Service and respective Regional Health Directors granted research permission and facilitated hospital visits.

Results

Of the 40 facilities assessed, 29 were district-level (23 government and 6 mission), 8 were regional and 3 were tertiary hospitals (Table 1).

District-level hospitals

Most pediatric resuscitation items had median availability ratings of 2 or 3 (i.e. airway equipment, oxygen supply, pulse oximeters, peripheral IV catheters, urinary catheters, blood transfusion capacity). However, there was considerable variation in the availability of the aforementioned items within the district-hospital level (rating range 0 – 3). For instance, 57% and 38% of district-level hospitals had median availability ratings less than 2 for pediatric basic airway supplies and urinary catheters, respectively. Further, pediatric cervical collars and chest tubes were often absent (median rating 0) despite their low-cost.

Though the median rating for hemoglobin test determination was 3, electrolyte testing and small-volume lab sampling were rarely available (median rating 0). Stationary X-ray had median rating of 2 or 3 at 61% of hospitals, but portable X-ray and focused assessment with sonography for trauma (FAST) scan were seldom available (median rating 0 or 1).

Regional hospitals

Regional hospitals had higher median availability ratings than district-level hospitals for several pediatric items: blood pressure cuffs (3 vs 1), urinary catheters (2.5 vs 2) and electrolyte testing capacity (1 vs 0). However, advanced airway equipment, cervical collars,

chest tubes, mechanical ventilators and electronic cardiac monitors were frequently not available (median rating less than 2) at regional hospitals.

As in district hospitals, blood electrolyte test capacity, small-volume lab sampling, portable X-ray and FAST scan were not often available (median rating less than 2).

Tertiary hospitals

Median availability rating for most pediatric resuscitation items was 3. However, basic airway equipment, cervical collars, blood pressure cuffs, blood transfusion capacity and electronic cardiac monitoring were not dependably available (median rating less than 3).

Small-volume lab sampling was only available at one tertiary hospital. Similarly, only one hospital was able to perform portable X-ray consistently.

Pediatric vs adult item availability

Nasogastric tubes and peripheral IV catheters were consistently supplied in all sizes and at all levels of care. Placement of any size chest tube was seldom available at the district and regional level (median rating 0), though dependable available for all sizes at tertiary hospitals (median rating 3) Pediatric cervical collars were rarely available at any level (median rating 0 – 1).

There was a discrepancy between availability of pediatric sizes and adult sizes for several items: airway equipment, blood pressure cuffs and urinary catheters. These differences were not unique to a specific level of care.

Though there was weak evidence for a difference in pediatric compared to adult item availability at district or tertiary hospitals ($p=0.09$ for both); there appeared to be greater difference between the two item groups at regional hospitals ($p=0.05$).

Factors contributing to non-availability

Non-availability in both district-level and large (regional and tertiary) hospitals was predominantly related to item absence (having never been present), insufficient supply or stock-outs or lack of training. Specifically, 18% of hospitals reported stock-outs for airway equipment, blood pressure cuffs, cervical collars and nasogastric tubes and 46% reported stock-outs for urinary catheters. A number of hospitals reported never having several essential items, specifically cervical collars (72% of district-level hospitals; 73% of large hospitals) and chest tubes (79% of district-level hospitals; 64% of large hospitals). All hospitals reported that item absence and stock-outs were, in part, the result of untimely National Health Insurance Scheme (NHIS) reimbursement rates, resulting insufficient operating budgets and being denied procurement requests when purchasing on credit.

Technology item non-availability was often due to breakage: 45% of X-ray, 27% of mechanical ventilator, 21% of pulse oximetry and 18% of electronic cardiac monitoring non-availability. Blood pressure cuffs were often not available as a result of loss Velcro (14% of district-level and 18% of large hospitals).

Lack of training resulted in non-availability of chest tubes at 18% of hospitals. Lastly, prohibitively expensive user fees prevented most children from having cervical collars, X-rays or mechanical ventilator support at 10% of large hospitals.

Discussion

This study aimed to identify health systems management (i.e. procurement, supply chain management, financing, training) and product development (i.e. developing more durable medical equipment) priorities for strengthening availability of resources pediatric trauma care in Ghana and other LMICs. Hospital assessments demonstrated marked essential deficiencies and lack of pediatric-sized items resulting from equipment absence, frequent stock-outs, lack of training, and technology breakage.

There have been few other assessments of pediatric trauma or surgical capacity in LMICs. In Sierra Leone, other than airway supplies, most pediatric items were considerably more deficient than were found in Ghana (e.g. IV and urinary catheters, NG tubes); trauma-related items, such as chest tubes and cervical collars, or factors contributing to deficiencies were not assessed for comparison.[23] Similar resuscitation item deficiencies were found in Uganda.[24] Using an assessment tool adapted from the Sierra Leone assessment (PediPIPES), a survey was distributed to surgeons at 37 hospitals in 10 African countries; most of which were tertiary hospitals.[25] Skill for chest tube insertion and essential non-drug consumables were reported to be widely variable (i.e. present in 49 – 95% of facilities). Chest tubes were noted to be among the least available supplies in both the multi-national survey and in this study. Aggregate results of these studies demonstrate not only deficiencies in essential items for pediatric trauma care, but items that are inexpensive and relatively easy to ship and store. Meanwhile, the successful availability of items requiring advanced inputs (e.g. laboratory equipment for hemoglobin determination, pulse oximetry, blood banking, ultrasonography) discovered by this study suggest that procurement and stock management practices could be improved with sustained commitment to provide more reliable availability of other essential trauma care items. Moreover, laboratory equipment that was procured and maintained with vertical programming funds (e.g. hemoglobin determination, blood banking) was not found to suffer from long periods of breakage, highlighting the beneficial effect of ensuring regular service and timely repairs by trained technicians on essential item availability.

Improving availability of consumables requires continual assessment of demand, regular inventory of supply and responsive feedback mechanisms to procurement agencies.[26, 27] Given the relatively recent recognition of injury as a public health dilemma in LMICs, particularly in the young population, lessons from other disease surveillance systems and established mechanisms for supply chain management of medical consumables are instructive. For instance, fifteen years of integrated community- and hospital-based surveillance of a number of communicable diseases (e.g. cholera, yellow fever, plague, meningitis) by national health systems and the WHO has led to a responsive network that adequately assesses, responds to and appropriately resources health facilities for changes in disease epidemiology; resultantly, timely care can be provided and prevention interventions accurately targeted.[28] Such mechanisms could be mirrored for injury surveillance and

medical input supply, or better, utilized in tandem to continually gather data useful for planning precise allocation of scarce resources. For assessing supply and activating restocking mechanisms before critical shortages occur, a recent mobile-health model has proven successful in East Africa. *SMS for Life*, a public-private partnership that uses text-messaging to flag low-stocks of anti-malarial drugs, was able to reduce stock-outs from 79 to 26% at health centers in rural Tanzania.[29] Given *SMS for Life* costs less than US\$ 80 per facility per year, similar systems for non-drug consumables (e.g. airway supplies, chest tubes) could be readily implemented in LMIC health systems.[26]

All hospitals were financially strained and often unable to purchase essential non-drug consumables due to untimely reimbursement rates by the NHIS. Though initially successful in improving access to care for Ghanaians and increasing hospital revenue, the NHIS has become unable to reimburse hospitals for the services rendered in a timely manner.[30, 31] Among the reasons for untimely reimbursements are: increasing reliance on a narrow tax base; caring for large informal populations; and witnessing greater than expected healthcare utilization.[30, 32, 33] In 2009, Atinga et al reported that half of hospital insurance claims were not reimbursed for 6 months, straining abilities to maintain predictable cash flow and deliver essential services.[34] During this study, most hospital administrations reported that reimbursements have been delayed 6 to 11 months. Further, Atinga et al reported that the current NHIS tariff structure does not adequately compensate hospitals for the services they provide given currency depreciation and increasing cost of many supplies; resultantly, healthcare delivery was challenging.[34] The intermittent reliance on purchasing essential supplies on credit discovered in 2009 was reported to be uniform practice during this assessment;[34] more concerning, some suppliers were no longer willing to accept procurement requests for essential trauma care items due to lack of ability to pay in cash. Given the high and increasing burden of trauma in LMICs and the significant loss of productivity resulting from injury and untimely service delivery, prioritizing financing of essential trauma care is vitally important.[1, 35-37] Studies from China and Turkey reported that productivity losses from injury resulted in tens of billions of US\$ per year.[36, 37] In LMICs where manual labor, sustenance work and high rates of family dependence on a single earner's income are common, identifying innovative ways to disrupt the perpetuating cycle of death and disability from injury and low development is imperative.[38] Not the least of these would be ensuring that hospitals are reliably resourced to provide timely essential trauma care to minimize death and disability after injury.[12, 39]

This study has several limitations that should be considered when interpreting its results. The rating scheme (0 – 3) was somewhat subjective. In an attempt to strengthen its validity, key informants from several departments that interact with the same item (i.e. X-ray – emergency room doctors, emergency room nurses, surgeons, nurse anesthetists, X-ray technicians, biomedical engineers) were asked about its availability to triangulate responses. Further, direct observation of equipment and supplies was performed. One regional and one tertiary hospital in a highly populated area declined participation. Their resource availability may be more or less than other facilities within the same healthcare level. The study did not systematically ensure that every pediatric size of each item was available. However, survey teams did ensure that a sufficient variety was present to care for

children of all ages, from neonates to adolescents. Attempts were made to understand the root causes of deficiencies; however, there were many externalities (i.e. beyond the hospital level) that we were unable to examine. Despite aforementioned limitations, these results provide a more useful assessment of pediatric trauma care capacity than previously reported from any LMIC. They allow reasonable conclusions to be drawn about ways to improve the reliability of trauma care items and services in Ghana. In addition, since several other LMICs have reported similar deficiencies, this study provides useful methods and instructive lessons for other healthcare systems that are attempting to understand and improve pediatric trauma care capacity.

Conclusion

This study identified several successes and problems with the availability of pediatric trauma care item availability in Ghana. Item availability could be improved, both affordably and reliably, by better organization and planning, such as: regular assessment of demand using established disease surveillance mechanisms; real-time bed-side inventory and feedback to procurement agencies to avoid stock-outs; and garnering political will to make provision of essential trauma care a healthcare financing priority in the setting of strained NHIS reimbursement. In addition, technology items were often broken. Developing local service and technical support capability was highlighted as a priority to avoid long periods of equipment breakage leading to essential item non-availability.

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Reference

1. IHME. Data Visualizations. Global Burden of Disease Cause Patterns. 2013. cited 2014 12/7/2014 Available from: <http://vizhub.healthdata.org/gbd-cause-patterns/>
2. WHO. Provisional agenda item 12.3. World Health Organization; Geneva: 2013. Sixty-sixth world health assembly: proposed programme budget 2014-2015.
3. Lozano R, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012; 380(9859):2095–128. [PubMed: 23245604]
4. Jurkovich GJ, Mock C. Systematic review of trauma system effectiveness based on registry comparisons. *J Trauma*. 1999; 47(3 Suppl):S46–55. [PubMed: 10496611]
5. Mann NC, et al. Systematic review of published evidence regarding trauma system effectiveness. *J Trauma*. 1999; 47(3 Suppl):S25–33. [PubMed: 10496607]
6. Nathens AB, et al. The effect of organized systems of trauma care on motor vehicle crash mortality. *JAMA*. 2000; 283(15):1990–4. [PubMed: 10789667]
7. Nathens AB, et al. Effectiveness of state trauma systems in reducing injury-related mortality: a national evaluation. *J Trauma*. 2000; 48(1):25–30. discussion 30-1. [PubMed: 10647561]
8. Kushner AL. A Proposed Matrix for Planning Global Surgery Interventions. *World J Surg*. 2014

9. LeBrun DG, et al. Prioritizing essential surgery and safe anesthesia for the Post-2015 Development Agenda: operative capacities of 78 district hospitals in 7 low- and middle-income countries. *Surgery*. 2014; 155(3):365–73. [PubMed: 24439745]
10. Gupta S, et al. Burn management capacity in low and middle-income countries: A systematic review of 458 hospitals across 14 countries. *Int J Surg*. 2014
11. Ologunde R, et al. Assessment of cesarean delivery availability in 26 low- and middle-income countries: a cross-sectional study. *Am J Obstet Gynecol*. 2014
12. Ozgediz D, et al. The burden of surgical conditions and access to surgical care in low- and middle-income countries. *Bull World Health Organ*. 2008; 86(8):646–7. [PubMed: 18797625]
13. Kingham TP, et al. Quantifying surgical capacity in Sierra Leone: a guide for improving surgical care. *Arch Surg*. 2009; 144(2):122–7. discussion 128. [PubMed: 19221322]
14. Shah MT, et al. Assessment of the Availability of Technology for Trauma Care in India. *World J Surg*. 2014
15. Wong EG, et al. Prioritizing injury care: a review of trauma capacity in low and middle-income countries. *J Surg Res*. 2014
16. Knowlton LM, et al. Liberian surgical and anesthesia infrastructure: a survey of county hospitals. *World J Surg*. 2013; 37(4):721–9. [PubMed: 23404484]
17. Linden AF, et al. Challenges of surgery in developing countries: a survey of surgical and anesthesia capacity in Uganda's public hospitals. *World J Surg*. 2012; 36(5):1056–65. [PubMed: 22402968]
18. Notrica MR, et al. Rwandan surgical and anesthesia infrastructure: a survey of district hospitals. *World J Surg*. 2011; 35(8):1770–80. [PubMed: 21562869]
19. US_Central_Intelligence_Agency. CIA World Factbook. Ghana. 2014. cited 2014 August 12th Available from: <http://www.cia-worldfactbook.us/africa/ghana.html>
20. Galukande M, et al. Essential surgery at the district hospital: a retrospective descriptive analysis in three African countries. *PLoS Med*. 2010; 7(3):e1000243. [PubMed: 20231871]
21. Chirdan LB, et al. Challenges of training and delivery of pediatric surgical services in Africa. *J Pediatr Surg*. 2010; 45(3):610–8. [PubMed: 20223329]
22. Stewart BT, et al. Strategic assessment of trauma care technology availability in Ghana. 2014 Submitted to peer-review journal.
23. Kushner AL, et al. Assessment of pediatric surgery capacity at government hospitals in Sierra Leone. *World J Surg*. 2012; 36(11):2554–8. [PubMed: 22851151]
24. Walker IA, et al. Paediatric surgery and anaesthesia in south-western Uganda: a cross-sectional survey. *Bull World Health Organ*. 2010; 88(12):897–906. [PubMed: 21124714]
25. Okoye MT, et al. A Pilot Survey of Pediatric Surgical Capacity in West Africa. *World J Surg*. 2014
26. Githinji S, et al. Reducing stock-outs of life saving malaria commodities using mobile phone text-messaging: SMS for life study in Kenya. *PLoS One*. 2013; 8(1):e54066. [PubMed: 23349786]
27. Mehralian G, et al. Developing a suitable model for supplier selection based on supply chain risks: an empirical study from Iranian pharmaceutical companies. *Iran J Pharm Res*. 2012; 11(1):209–19. [PubMed: 24250442]
28. WHO. Partnership in Outbreak Response. World Health Organization; Geneva: 2014. Global Outbreak Alert and Response Network-GOARN.
29. Barrington J, et al. SMS for Life: a pilot project to improve anti-malarial drug supply management in rural Tanzania using standard technology. *Malar J*. 2010; 9:298. [PubMed: 20979633]
30. Sodzi-Tetty S, et al. Challenges in provider payment under the Ghana National Health Insurance Scheme: a case study of claims management in two districts. *Ghana Med J*. 2012; 46(4):189–99. [PubMed: 23661837]
31. Dalinjong PA, Laar AS. The national health insurance scheme: perceptions and experiences of health care providers and clients in two districts of Ghana. *Health Econ Rev*. 2012; 2(1):13. [PubMed: 22828034]
32. Lagomarsino G, et al. Moving towards universal health coverage: health insurance reforms in nine developing countries in Africa and Asia. *Lancet*. 2012; 380(9845):933–43. [PubMed: 22959390]

33. McIntyre D, et al. Beyond fragmentation and towards universal coverage: insights from Ghana, South Africa and the United Republic of Tanzania. *Bull World Health Organ.* 2008; 86(11):871–6. [PubMed: 19030693]
34. Atinga RA, et al. Migrating from user fees to social health insurance: exploring the prospects and challenges for hospital management. *BMC Health Serv Res.* 2012; 12:174. [PubMed: 22726666]
35. Grimes CE, et al. Cost-effectiveness of surgery in low- and middle-income countries: a systematic review. *World J Surg.* 2014; 38(1):252–63. [PubMed: 24101020]
36. Naci H, Baker T. Productivity losses from road traffic deaths in Turkey. *International Journal of Injury Control and Safety Promotion.* 2008; 15:19–20. [PubMed: 18344092]
37. Zhou Y, et al. Productivity losses from injury in China. *Injury Prevention.* 2003; 9:124–127. [PubMed: 12810737]
38. Wesson HK, et al. The cost of injury and trauma care in low- and middle-income countries: a review of economic evidence. *Health Policy and Planning.* 2014
39. Mock C. Confronting the global burden of surgical disease. *World J Surg.* 2013; 37(7):1457–9. [PubMed: 23674258]

Table 1
Availability ratings of pediatric resuscitation items and services at hospitals in Ghana

	<u>Median item availability rating (range)</u>					
	District-level		Regional		Tertiary	
Number assessed	29		8		3	
Airway						
Basic equipment *	2	(0-2)	1	(0-2)	1.5	(1-2)
Advanced equipment *	2	(0-2)	0.5	(0-2)	3	
Nasogastric tube *	3	(0-3)	3	(0-3)	3	(2-3)
Cervical collar *	0	(0-3)	0	(0-1)	1	(0-1)
Breathing						
Oxygen supply	3	(1-3)	3	(2-3)	3	(2-3)
Chest tubes and water seal *	0	(0-2)	0	(0-2)	3	
Pulse oximetry	3	(0-3)	2	(2-3)	3	
Mechanical ventilator	2	(0-2)	1	(0-3)	3	(1-3)
Circulation						
Blood pressure cuff*	1	(0-3)	2.5	(0-3)	1	(0-3)
Peripheral IV catheter*	3	(1-3)	3	(2-3)	3	
Blood transfusion ability	2	(1-3)	2	(1-3)	2	(2-3)
Electronic cardiac monitoring	0	(0-2)	1	(0-2)	2	(1-2)
Urinary catheter*	2	(0-3)	2.5	(0-3)	2	(1-3)
Laboratory						
Hemoglobin	3	(1-3)	3	(2-3)	3	
Electrolytes	0	(0-3)	1	(0-2)	2	(0-2)
Small-volume sampling*	0	(0-3)	0	(0-1)	0	(0-3)
Imaging						
X-rays	2	(0-3)	2	(0-3)	2	(2-3)
Portable X-rays	0	(0-3)	0	(0-1)	1	(0-3)
FAST scan	0	(0-3)	0	(0-2)	3	(0-3)

IV – intravenous; FAST - focused assessment with sonography for trauma

* pediatric sizes

Table 2
Pediatric and adult trauma resuscitation item availability in Ghana

Item	Median item availability rating					
	District-level		Regional		Tertiary	
	Pediatric	Adult	Pediatric	Adult	Pediatric	Adult
Basic airway equipment	2	2	1	2	1.5	2
Advanced airway equipment	2	3	0.5	3	3	3
Nasogastric tube	3	3	3	3	3	3
Cervical collar	0	0	0	0	1	1
Chest tubes and water seal	0	0	0	0	3	3
Blood pressure cuff	1	3	3	3	1	3
Peripheral IV catheter	3	3	3	3	3	3
Urinary catheter	2	3	2.5	3	2	3
Comparison						
Assessment median	2	3	2.5	3	1	3
<i>p</i> -value*	0.09		0.05		0.09	

IV – intravenous; *p*-value for difference between pediatric and adult item availability at each hospital level using Wilcoxon signed-rank test

Table 3
Contributing factors for pediatric trauma care item non-availability at hospitals in Ghana

	Equipment absence	Broken	Personnel shortage	Lack of training	Lack of reagents	Stock-out, insufficient quantity	User fees necessary
District and mission hospitals							
Basic airway equipment *						21	
Advanced airway equipment *	10			4		45	
Nasogastric tube *	7					10	
Cervical collar *	72					28	
Chest tube and underwater seal *	79			17		4	
Blood pressure cuff *	24	14				24	
Peripheral IV catheter *						7	
Urinary catheter *	24					28	
Small-volume lab sampling *	79		10	4		4	
Pulse oximetry	7	21				24	
X-ray	24	45	14	4		10	
Regional and tertiary hospitals							
Basic airway equipment *						28	
Advanced airway equipment *						28	
Nasogastric tube *						18	
Cervical collar *	73					18	9
Chest tube and underwater seal *	64			18		9	
Blood pressure cuff *	27	18				18	
Peripheral IV catheter *						9	
Urinary catheter *	9					46	
Small-volume lab sampling *	82		9				
Pulse oximetry		27				36	
X-ray	9	46	27			9	9
Mechanical ventilator	18	27				27	9
Electronic cardiac monitoring	27	18				55	

IV – intravenous

* pediatric-specific items; Contributing factors were not considered mutually exclusive except when items had never been present at a facility. Therefore, some totals sum to more than 100%.

APPENDIX 9 - AVAILABILITY OF RESOURCES FOR
EMERGENCY CARE AT A SECOND-LEVEL HOSPITAL IN
GHANA: A MIXED METHODS ASSESSMENT



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Availability of resources for emergency care at a second-level hospital in Ghana: A mixed methods assessment

Disponibilité des ressources allouées aux soins d'urgence dans un hôpital de deuxième niveau au Ghana: évaluation de méthodes combinées

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Introduction: Emergency care is an essential component of health systems, particularly in low- and middle-income countries. We sought to assess the availability of resources to provide emergency care at a second-level hospital in Ghana. By doing so, deficits that could guide development of targeted intervention strategies to improve emergency care could be identified.

Methods: A qualitative and quantitative assessment of capacity for care of emergency patients was performed at the Emergency Centre of the Police Hospital, a second-level hospital in Accra, Ghana. Direct inspection and job-specific survey of clinical, orderly, administrative and ambulance staff was performed. Responses to quantitative questions were described. Qualitative responses were examined by content analysis.

Results: Assessment revealed marked deficiencies in many essential items and services. However, several successes were identified, such as laboratory capacity. Among the unavailable essential items, some were of low-cost, such as basic airway supplies, chest tubes and several emergency medications. Themes from staff responses when asked how to improve emergency care included: provide periodic training, increase bed numbers in the emergency unit, ensure availability of essential items and make personal protective equipment available for all staff caring for patients.

Conclusion: This study identified opportunities to improve the care of patients with emergency conditions at the Police Hospital in Ghana. Low-cost improvements in training, organization and planning could improve item and service availability, such as: developing a continuing education curriculum for staff in all areas of the emergency centre; holding in-service training on existing protocols for triage and emergency care; adding checklists to guide appropriate triage and safe transfer of patients; and perform a root cause analysis of item non-availability to develop targeted interventions.

Introduction: Les soins d'urgence sont une composante essentielle des systèmes de santé, notamment dans les pays à faible et moyen revenus. Nous avons cherché à évaluer la disponibilité des ressources allouées aux soins d'urgence dans un hôpital de deuxième niveau au Ghana. Il serait ainsi possible d'identifier les lacunes et ainsi guider le développement de stratégies d'intervention ciblées afin d'améliorer les soins d'urgence.

Méthodes: Une évaluation qualitative et quantitative de la capacité de prise en charge des urgences a été réalisée au sein de l'Unité accidents et urgences de l'hôpital de la Police, un hôpital de second niveau situé à Accra, au Ghana. Un examen direct et propre à la profession a été réalisé à propos du personnel soignant, administratif et ambulancier. Les réponses aux questions quantitatives ont été décrites. Les réponses qualitatives ont été examinées par une analyse de leur contenu.

Résultats: L'évaluation a révélé des déficiences prononcées dans nombre d'articles et services essentiels. Cependant, plusieurs succès ont été enregistrés, tels que la capacité des laboratoires. Parmi le matériel essentiel faisant défaut, il s'agissait pour certains de matériel peu coûteux, comme les dispositifs d'alimentation des voies aériennes de base, les drains thoraciques et plusieurs traitements d'urgence. Les réponses fournies par le personnel à la question de savoir comment améliorer les soins d'urgence incluait les thèmes suivants: l'accès à une formation périodique, l'augmentation du nombre de lits au sein des urgences, la garantie de la disponibilité du matériel essentiel, et la mise à disposition de tous les employés s'occupant des urgences d'un équipement de protection individuelle.

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Conclusion: Cette étude a identifié des opportunités d'amélioration de la prise en charge des urgences au sein de l'hôpital de la Police au Ghana. Des améliorations peu coûteuses en termes de formation, d'organisation et de planification pourraient améliorer la disponibilité du matériel et du service, telles que l'élaboration d'un programme d'enseignement médical continu dans tous les domaines du centre des urgences, la tenue d'une formation interne sur les protocoles de triage et de soins d'urgence existants, l'ajout de listes de vérification afin de permettre un triage approprié et le bon transfert des patients, et la conduite d'une analyse des causes premières de la non-disponibilité de matériel afin d'élaborer des interventions ciblées.

African relevance

- Secondary-level hospitals play an integral role in hierarchical African healthcare systems.
- Staff responses highlighted need for in-service training.
- Personal protective equipment (PPE) should be available to anyone with patient or potentially-hazardous material contact.

Introduction

Emergency care is an essential component to health systems and of growing importance given the increasing burden of medical, surgical and traumatic emergency conditions.^{1,2} Inopportunistly, this burden is highest in low- and middle-income countries (LMICs), which are least prepared to evaluate and treat emergency conditions due to deficiencies in organization and planning, trained personnel and physical resources.³⁻⁵ In response, efforts have been made to develop capacity and quality improvement programs for emergency care in LMICs.^{6,7}

Most emergency health system strengthening efforts have focused attention at the pre-hospital level and first- and tertiary-level hospitals.⁸⁻¹⁰ In Ghana, this has been evidenced by the foundation of a National Ambulance Service, investment in district-level obstetric emergency care and creation of an emergency medicine residency training program at a teaching hospital.^{6,11,12} Second-level hospitals are often overlooked during these important capacity building initiatives, yet are an important essential for emergency care in most LMIC healthcare systems.¹³

Second-level hospitals are in a challenging position in the healthcare hierarchy of LMICs. They receive patients referred from district-level hospitals, many of whom have had prolonged pre-hospital times, were under-resuscitated and arrive in urgent need of prompt diagnosis and treatment to avert preventable death and disability.¹³ However, some advanced diagnostics and definitive care items are infrequently available at these facilities (e.g. computed tomography scan, neurosurgery), requiring safe transfer to higher levels of care.⁵ Despite the integral role these hospitals occupy in LMIC emergency systems, emergency care capacity assessments at second-level facilities are underrepresented in the literature.¹⁴⁻¹⁸

To address this gap, we sought to assess the availability of resources to provide emergency care at a second-level hospital in Ghana. By doing so, the findings might identify deficits in the essential components of second-level hospitals that would allow development of targeted intervention strategies to improve emergency care.

Methods

Ghana is a heavily indebted, lower-middle income country in West Africa with a population of 26 million people and an

annual per capita income of US\$ 1760.¹⁹ Ghana has 10 regions divided into 110 districts. Most districts have several primary health centres (PHC) and a government or mission hospital that serves as a district (first-level) hospital. PHCs provide only basic public health and primary care services. Subsequently, most emergency cases are referred to district-level hospitals. District-level hospitals are staffed by medical officers and nurse anaesthetists, typically offer some surgical services and have between 50 and 100 beds. Emergencies requiring more complex care are referred to one of the regional or four teaching hospitals. In addition to medical officers and nurse anaesthetists, second-level (regional) hospitals are staffed by specialist providers (e.g. paediatricians, obstetricians, and general and orthopaedic surgeons) and contain between 100 and 400 beds. Emergency and surgical services offered at regional hospitals are broader in scope. However, sub-specialist care (e.g. cardiology, neurosurgery, critical care) is usually not present. Therefore, patients requiring advanced care are referred to a tertiary facility.

Among the second-level hospitals is the Police Hospital in Accra. Though initially developed to care for police service-members and their families, the crowded healthcare system has required the Police Hospital to care for any patient with medical, surgical and traumatic emergencies from the surrounding area. The hospital receives emergency cases from the eastern area of Accra, as the tertiary care centre is in western Accra and is difficult to reach when traffic is congested. The Police Hospital also receives referrals from district-level hospitals around the country.

To assess emergency care capacity, a survey instrument was developed to capture staff perceptions of and/or challenges with the availability of emergency care services and the resources (human and physical) needed to provide these services. Staff members working at the Emergency Centre of the Police Hospital were purposively sampled to represent all professions necessary for emergency care. Variations of the survey instrument were used for collecting job-specific data from different staff (e.g. ambulance drivers, orderlies, clinicians, and administrators) and some sections that were not applicable to a specific job were omitted.

The instruments assessed trauma care items considered essential by the Ghana Health Service (GHS) Emergency Supply Checklist or the World Health Organization's (WHO) *Guidelines for essential trauma care or Integrated management for emergency and essential surgical care (IMEESC) tool kit*.²⁰⁻²² Staff members based in the Emergency Centre were asked about the availability of each item. In addition, direct inspection was used to corroborate reported item availability. Item availability was rated as: 0 – Absent but should be present; 1 – Inadequate, available to less than half of those who need it; 2 – Partially adequate, available to more than half, but not to everyone who needs it; or 3 – Adequate, present and readily available to almost everyone in need and used when needed. Staff members were also asked about their

opinions on ways to overcome deficiencies and to strengthen emergency care provided at the hospital.

Data were collected in 2014. Data were collected on paper forms and entered into Microsoft Excel (Redmond, WA, USA). Responses to quantitative questions were described using Stata v13 (College Station, TX, USA). The proportion of essential items available, as recommended by the GHS or WHO essential emergency equipment and supply list, were tabulated and plotted. Responses to qualitative questions on recommendations for strengthening care were examined using a content analysis framework.²³ First, qualitative responses were grouped into categories based on codes representing clustered responses. Next, categories were further refined into useful themes and described. Responses were triangulated between staff of different professions and within the same profession to evaluate the extent of theme convergence.

The Kwame Nkrumah University of Science and Technology Committee for Human Research and Publication Ethics and the leadership of the Police Hospital approved this study. The study was considered exempt by the University of Washington Institutional Review Board. Survey procedures were explained to each participant, and participants provided informed consent prior to survey. All data were collected anonymously.

Results

A total of 78 of the 80 (98%) approached emergency care personnel participated in the assessment. These included 44 clinical staff (56%; 24 nurses, 13 medical officers and 7 ambulance crew members) and 34 non-clinical staff (44%; 23 orderlies and 11 administrative staff).

Regarding physical resources for resuscitation, several items were consistently available with ratings of 3 (e.g. Magill forceps, stethoscope, blood pressure cuff, IV catheter and infusion set, urinary catheter). Some items were less available (i.e. rating 1 or 2), including basic airway adjuncts, oxygen supply, pulse oximetry and cervical collars. Most other items were not available, particularly medical technology (e.g. cardiac monitors, ventilators, defibrillator). Despite being a referral hospital for trauma and obstetric emergencies, blood transfusion capabilities were not present (Table 1).

No diagnostic imaging service was reliably available (i.e. ratings were less than 3). There was no portable X-ray, ultrasound machine or image intensification. Several essential laboratory items were intermittently available (i.e. rating 1 or 2), such as glucometry, haemoglobin determination, gram stain and urinalysis (Table 2).

Though equipment for several emergency care procedures was available intermittently (e.g. wound closure, surgical airway, lumbar puncture), none had ratings greater than 1. Other procedure trays were not available, including diagnostic peritoneal lavage. Notably, other than gloves, all essential personal protective equipment (PPE) items were not reliably available, including safe sharps and biological waste disposal, goggles or post-exposure prophylaxis for HIV (ratings 1 or 2) (Table 3).

Nearly 60% of essential medications were in stock with some availability; however, no medication was reliably available (i.e. no rating of 3). Several WHO groups of medica-

Table 1 Essential items recommended by the World Health Organization or Ghana Health Service at the Emergency Centre in Ghana Police Hospital.

	WHO/GHS recommendation	Police Hospital
Airway		
Nasal or oral airway	E	1
Suction pump, tubing and tip	E	1
LMA or Combitube	G	0
Laryngoscope	E	0
Endotracheal tube	E	0
Elastic gum bougie	G	0
Bag-valve-mask	E	1
Magill forceps	E	3
Nasogastric tube	E	3
Capnography	D	0
Breathing		
Stethoscope	E	3
Oxygen supply	E	1
Nasal prongs, face mask	E	0
Chest tube and underwater seal	E	0
Nebulizer	G	1
Pulse oximetry	D	1
Peak flow meter	G	0
Transport ventilator	G	0
Mechanical ventilator	D	0
Circulation		
Blood pressure cuff	E	3
Bandages	E	3
Arterial tourniquet	E	3
IV catheter and fluid set	E	3
Blood transfusion capabilities	E	0
Intraosseous needles	E	0
Central venous catheter	E	0
Urinary catheter	E	3
Electronic cardiac monitoring	D	0
Defibrillator	G	0
Fluid warmer	D	0
Disability		
Cervical collar	E	2
Spine board	E	0
Long-bone splints	E	2
Closed reduction	E	1
Plaster of Paris	E	2
Measurement of compartment pressure	E	2

WHO/GHS – World Health Organization/Ghana Health Service; E – item considered essential for emergency care at second-level hospitals by the WHO; D – item considered desirable for second-level hospitals by the WHO; G – item considered essential for emergency care by GHS; rating scheme: 0 – absent; 1 – inadequate, available to less than half of those who need it; 2 – partially adequate, available to more than half, but not to most who need it; 3 – adequate, present and readily available to almost everyone in need and used when needed. LMA – laryngeal mask airway; IV – intravenous.

tions were not present; there were no anticonvulsants (other than diazepam), tocolytics, blood products, muscle relaxants or tetanus immunoglobulin. In addition, several drugs essential in managing adverse events related to iatrogenic overdose, namely naloxone and glucagon, were not

Table 2 Emergency diagnostic capacity at the Emergency Centre in Ghana Police Hospital.

	WHO/GHS recommendation	Police Hospital
Diagnostic imaging		
X-ray	E	1
Portable X-ray	D	0
Ultrasound machine	E	0
Image intensification	E	0
Contrast radiography	E	0
CT scan	D	0
Laboratory		
Glucometer	G	2
Haemoglobin determination	E	2
Blood electrolyte determination	D	0
Gram stain	E	2
Bacterial cultures	D	2
Serum lactate	D	2
Urinalysis	G	2

WHO/GHS – World Health Organization/Ghana Health Service; E – item considered essential for emergency care at second-level hospitals by the WHO; D – item considered desirable for second-level hospitals by the WHO; G – item considered essential for emergency care by GHS; rating scheme: 0 – absent; 1 – inadequate, available to less than half of those who need it; 2 – partially adequate, available to more than half, but not to most who need it; 3 – adequate, present and readily available to almost everyone in need and used when needed. CT – computed tomography.

Table 3 Emergency procedure capacity and personal protective equipment availability at the Emergency Centre in Ghana Police Hospital.

	WHO/GHS recommendation	Police Hospital
Procedural equipment trays		
Wound closure	E	1
Surgical airway	E	1
Venous cutdown	G	0
Diagnostic peritoneal lavage	E	0
Burr hole	D	0
Skin or skeletal traction	E	1
Lumbar puncture	G	1
Suprapubic catheterization	G	1
Personal protective equipment		
Disposable gloves	E	3
Goggles	E	2
Safe sharps disposal	E	1
Biological waste disposal	E	1
Gowns	E	2
Post-exposure prophylaxis for HIV	D	2

WHO/GHS – World Health Organization/Ghana Health Service; E – item considered essential for emergency care at second-level hospitals by the WHO; D – item considered desirable for second-level hospitals by the WHO; G – item considered essential for emergency care by GHS; rating scheme: 0 – absent; 1 – inadequate, available to less than half of those who need it; 2 – partially adequate, available to more than half, but not to most who need it; 3 – adequate, present and readily available to almost everyone in need and used when needed.

available (Table 4). Fig. 1 demonstrates the relative deficiencies of each category of emergency care equipment and supplies. Notably, no component of the capacity assessment demonstrated adequate availability of essential items. Critical deficits included diagnostic imaging, airway and breathing items for resuscitation and emergency medications. Laboratory equipment and supplies were the most available; however, they did not reach 70% of expected availability based on WHO and GHS recommendations.

Across areas in the emergency unit, the majority of staff recommended training of new and current staff in triage and emergency care procedures (range 82–89%). Along these lines, only 7% of all respondents indicated that they had undergone regular job-specific training. Improvements or expansion in infrastructure and bed space was suggested by clinical and non-clinical staff (36% and 24%, respectively). Both clinical (34; 77%) and non-clinical staff (27; 79%) reported the need to ensure the availability of essential emergency equipment and supplies to improve care (Table 5). Several non-clinical staff recommended making PPE available for all staff that care for patients or handle potentially contaminated materials, suggesting that these items were not easily accessible by this subgroup.

Discussion

This study sought to measure emergency care capacity at a second-level hospital in Ghana and identify deficits that would benefit from targeted intervention at this level. The results demonstrate a critical lack of job-specific continuing education and training among all staff members and shortages or an absence of many essential emergency care items and medications, including several low-cost items (e.g. airway supplies, chest tubes, PPE). Despite these deficiencies, several successes were identified, such as availability of essential laboratory services.

The most common recommendation for improvement in emergency capacity was increase in job-specific training. Even faced with critical resource deficits, significant improvements to emergency care have been achieved with staff training and process improvement. For example, pre-hospital care training designed for community members in Iraq and Cambodia reduced trauma-related mortality from 40% to 15% over four years.²⁴ Similarly, hospital-based care training for triage, trauma and emergency obstetric and paediatric care have resulted in reductions in mortality, recognition of patients in need of transfer and identification of patients in need of prompt intervention.^{7,8,25–27} In Ghana, there have been several efforts to improve emergency care training that could be used at the Police Hospital and in other LMIC second-level hospitals. Of these, one was an annual university-led, government-funded continuing education program for injury care targeting district-level hospital providers that ran from 1996 to 2011. An assessment of the courses was reported in 2004.²⁸ Pre- and post-test scores documented good retention of the program's content and follow-up assessments between 6 months and 2 years after the training demonstrated that program participants were significantly more comfortable with trauma management principles and procedures covered by the program. The Ministry of Health and the hospitals of participants shouldered the entire expense of the courses (individual participant

Table 4 Essential medication availability at the Emergency Centre in Ghana Police Hospital.

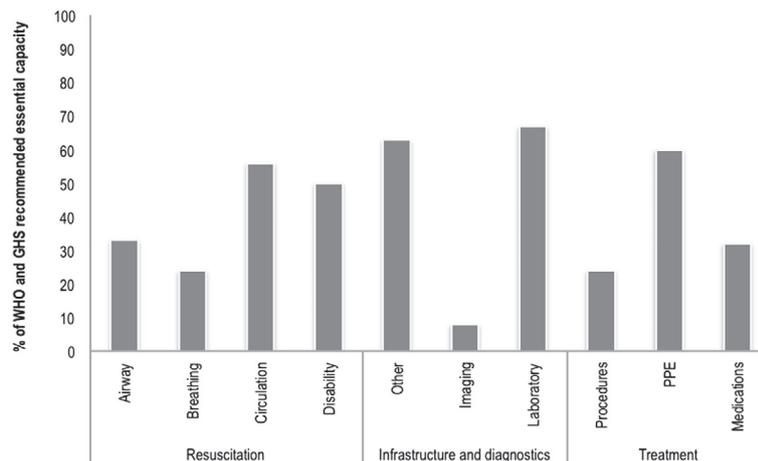
	WHO/GHS recommendation	Police Hospital
Anaphylaxis		
Epinephrine	E	2
Hydrocortisone	E	2
Anaesthesia		
Diazepam	E	2
Etomidate	G	0
Ketamine	E	2
Local anaesthetic	E	2
Midazolam	E	0
Neostigmine	G	0
Propofol	G	0
Suxamethonium	E	0
Vecuronium	E	0
Anticonvulsants		
Magnesium sulphate	E	0
Phenobarbital	E	0
Phenytoin	E	0
Antiseptics and disinfectants		
Antiseptics (e.g. polyvidone, ethanol)	E	2
Disinfectants (e.g. chlorine base solutions)	E	2
Pulmonary disorders		
Salbutamol	G	2
Burn care		
Silver sulfadiazine	E	2
Cardiovascular disorders		
Dopamine	D	0
Atropine	D	0
Dobutamine	G	0
Hydralazine	E	2
Labetalol	G	0
Nitroglycerine	G	0
Norepinephrine	G	1
Phenylephrine	G	0
Diuretics		
Furosemide	E	1
Mannitol	D	0
Fluid, blood products, plasma expanders		
5% & 50% glucose solution	E	2
Fresh frozen plasma	G	0
Isotonic saline	E	1
O-negative whole blood	E	0
Plasma expanders	D	0
Ringer's lactate	E	2
Sodium bicarbonate	G	0
Gastrointestinal disorders		
Antacid	E	0
Oral rehydration salts	E	2
Hormone disorders		
Glucagon	E	0
Insulin	E	2
Infections		
Spectrum of antibiotics	E	2
Medications affecting blood		
Aspirin	E	2
Heparin	E	1
Vitamin K	G	1

(continued on next page)

Table 4 (continued)

	WHO/GHS recommendation	Police Hospital
Minerals		
Calcium chloride or gluconate	D	1
Potassium solution	E	1
Pain, fever, inflammation		
Acetaminophen	E	2
Ibuprofen	E	2
Narcotic analgesia	E	1
Poisoning, envenomation, wounds		
Appropriate snake species antivenom	G	0
Naloxone	E	0
Tetanus immunoglobulin	E	0
Tetanus toxoid	E	1

WHO/GHS – World Health Organization/Ghana Health Service; E – item considered essential for emergency care at second-level hospitals by the WHO; D – item considered desirable for second-level hospitals by the WHO; G – item considered essential for emergency care by GHS; rating scheme: 0 – absent; 1 – inadequate, available to less than half of those who need it; 2 – partially adequate, available to more than half, but not to most who need it; 3 – adequate, present and readily available to almost everyone in need and used when needed.



WHO/GHS – World Health Organization/Ghana Health Service; PPE – personal protective equipment

Figure 1 Availability of essential resuscitation, infrastructure, diagnostics and definitive emergency care at the Emergency Centre in Ghana Police Hospital. WHO/GHS – World Health Organization/Ghana Health Service; PPE – personal protective equipment.

Table 5 Recommendations by staff at the Emergency Centre in Ghana Police Hospital for improvements in emergency services.

	Clinical		Non-clinical	
	<i>n</i> = 44		<i>n</i> = 34	
	<i>n</i>	(%)	<i>n</i>	(%)
Regular training for new and current staff	39	(89)	28	(82)
Improve infrastructure, bed space	16	(36)	8	(24)
Ensure availability of essential items/medications	34	(77)	27	(79)
Make PPE available to all staff caring for patients	0	(0)	4	(12)

PPE – personal protective equipment; staff include 24 nurses, 13 medical officers and 7 ambulance crew members; non-clinical staff include 23 orderlies and 11 administrative staff.

cost was US\$ 135). Given the affordability and success of these training interventions and the lack of training and knowledge deficiencies reported by the respondents, re-invigorating the emergency care training course and including second-level hospitals would be a meaningful intervention. Often in training, pre-hospital, orderly and nursing staff are left out. Though separate coursework would be required, ensuring adequate training in all members of the emergency care team is important for success in emergency care quality improvement.^{12,29}

In terms of physical resources, other assessments of emergency capacity at second-level hospitals have been reported. In Sierra Leone, stable electricity, blood transfusion capabilities, cardiac monitoring and low-cost non-drug consumables, such as chest tubes and cervical collars were regularly not present.³⁰ Similar patterns of equipment, supply and medication deficiencies from second-level hospitals in Kenya, Uganda, Malawi and Nicaragua suggest that the capacity gap found at the Police Hospital is not unique. Therefore, committed attention to improve essential item availability to this keystone of LMIC referral systems is urgently needed.^{31–34}

Though this study demonstrated a number of deficiencies in equipment, supplies and medications necessary for basic emergency care, the root causes of the deficiencies were not assessed. In Gujarat State, India, a systematic assessment of the causes of essential trauma care item deficiencies was undertaken. The authors described a lack of numerous specific items due to stock-outs and equipment breakdowns. By doing so, they were able to identify several potential interventions for improving item availability, including: better procurement and stock-management; optimizing training for use of existing resources; and strengthening service contracts and local repair capabilities.⁵ Similar assessments performed at the hospital-level may be able to distinguish between deficiencies due to externalities and those resulting from lack of organization and planning; the latter can often be improved low-cost interventions. Performing capacity assessments can be made richer by including evaluation of the causes of essential item deficiencies (e.g. lack of trained personnel, inefficient procurement process, lack of technicians to service broken technology, poor stock management of essential medications). Once this information is obtained, health systems can target interventions to improve the availability of essential emergency items and services.

The main limitation of this study was that objective data on practices of triage, emergency treatment and patient transfers were not collected. However, questions were triangulated between and within staff at different areas of the emergency unit to ensure responses most accurately reflect the real situation and available resources. For example, a specific concern not identified by other staff was the lack of PPE available to staff who transport patients, despite PPE being one of the items most available during direct observation. Lastly, in-depth focus group discussions that may have added richness to qualitative responses were not done. However, responses were clustered around the themes presented and no response was omitted from being presented in the results. Despite these limitations, this mixed-methods study gives a hypothesis-generating understanding of actual and perceived challenges faced by emergency care personnel at a resource-limited second-level hospital. Thus, specific areas requiring further examination (e.g. causes of deficiencies, transfer process) and targeted interventions (e.g. in-service training) can be developed.

Conclusion

This study identified a number of challenges in care of patients with emergency conditions at the Police Hospital in Ghana. In addition, several successes were identified, for instance laboratory capacity. Low-cost improvements in training, organization and planning could affordably improve item and service availability, such as: developing a continuing education curriculum for staff in all areas of the emergency unit; holding in-service training on existing protocols for triage and emergency care; adding checklists to guide appropriate triage and safe transfer of patients; and performing an analysis of the root causes of item non-availability to develop targeted interventions. Regarding specific essential items, ensuring that low-cost consumables are reliably in-stock, such as airway supplies, chest tubes, glucagon and tocolytics, is an important first step in improving emergency care capacity.

Author's contributions

KBJ, GA, EOD, BTS, BEE and CNM designed the study. KBJ and GA collected data. KBJ, BTS, and PD analysed and interpreted the data. KBJ and BTS prepared the first manuscript draft. All authors contributed significantly and critically to the final manuscript.

Conflict of interest

The authors declare no conflict of interest. This study was funded in part by grants from the Fogarty International Center, US National Institutes of Health (R25-TW009345; D43-TW007267).

Dissemination of results

Results from this study were shared with staff members at the Police Hospital Emergency Centre and with the hospital administration prior to publication.

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References

1. Stewart B, Khanduri P, McCord C, et al. Global disease burden of conditions requiring emergency surgery. *Br J Surg* 2014;**101**(1): e9–e22.
2. Lozano R, Naghavi M, Foreman K, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;**380**(9859):2095–128.
3. Wong EG, Gupta S, Deckelbaum DL, et al. Prioritizing injury care: a review of trauma capacity in low and middle-income countries. *J Surg Res* 2014.

4. Mock C, Quansah R, Kobusingye O, et al. Trauma care in Africa: the way forward. *Afr J Trauma* 2014;**3**(1):3–10.
5. Shah MT, Joshipura M, Singleton J, et al. Assessment of the availability of technology for trauma care in India. *World J Surg* 2014;**39**(2):363–72.
6. Mock C, Juillard C, Joshipura M, et al. *Strengthening care for the injured: success stories and lessons learned from around the world*. Geneva: World Health Organization; 2010.
7. Son NT, Mock C. Improvements in trauma care capabilities in Vietnam through use of the WHO-IATSIC Guidelines for Essential Trauma Care. *Int J Inj Contr Saf Promot* 2006;**13**(2):125–7.
8. Henry JA, Orgoi S, Govind S, et al. Strengthening surgical services at the soum (first-referral) hospital: the WHO emergency and essential surgical care (EESC) program in Mongolia. *World J Surg* 2012;**36**(10):2359–70.
9. Muecke S, Curac N, Binks D. Informing clinical policy decision-making practices in ambulance services. *Int J Evid Based Healthc* 2013;**11**(4):299–304. <http://dx.doi.org/10.1111/744-609.12039>.
10. Mock CN, Tiska M, Adu-Ampofo M, et al. Improvements in prehospital trauma care in an African country with no formal emergency medical services. *J Trauma* 2002;**53**(1):90–7.
11. Abdullah F, Choo S, Hesse AA, et al. Assessment of surgical and obstetrical care at 10 district hospitals in Ghana using on-site interviews. *J Surg Res* 2011;**171**(2):461–6.
12. Martel J, Oteng R, Mould-Millman NK, et al. The development of sustainable emergency care in Ghana: physician, nursing and prehospital care training initiatives. *J Emerg Med* 2014;**47**(4):462–8.
13. Nordberg E, Holmberg S, Kiugu S. Exploring the interface between first and second level of care: referrals in rural Africa. *Trop Med Int Health* 1996;**1**(1):107–11.
14. Ankomah J, Stewart BT, Oppong-Nketia V, et al. Strategic assessment of the availability of pediatric trauma care equipment, technology and supplies in Ghana. *J Pediatr Surg* 2015.
15. Stewart B, Quansah R, Gyedu A, et al. Strategic assessment of trauma care technology availability in Ghana. *World J Surg* 2015;**39**(10):2428–40.
16. Hardcastle TC, Samuels C, Muckart DJ. An assessment of the hospital disease burden and the facilities for the in-hospital care of trauma in KwaZulu-Natal, South Africa. *World J Surg* 2013;**37**:1550–61.
17. Burke TF, Hines R, Ahn R, et al. Emergency and urgent care capacity in a resource-limited setting: an assessment of health facilities in western Kenya. *BMJ Open* 2014;**4**:e006132.
18. Mock C, Nguyen S, Quansah R, Arreola-Risa C, Viradia R, Joshipura M. Evaluation of Trauma Care capabilities in four countries using the WHO-IATSIC Guidelines for Essential Trauma Care. *World J Surg* 2006;**30**(6):946–56.
19. CIA World Factbook: United States Central Intelligence Agency; 2014 cited 2015 April 12th. Available from: <<http://www.cia-worldfactbook.us/africa/ghana.html>> .
20. Amoah AGB, Bannerman C, Zacharia A, et al. *Policy and guidelines for hospital accident and emergency services in Ghana*. Accra, Ghana: Ministry of Health; 2011.
21. Mock C, Lormand J, Goosen J, et al. *Guidelines for essential trauma care*. Geneva: World Health Organization; 2004.
22. WHO. *WHO generic essential emergency equipment list*. Geneva: World Health Organization; 2003.
23. Bradley EH, Curry LA, Devers KJ. Qualitative data analysis for health services research: developing taxonomy, themes, and theory. *Health Serv Res* 2007;**42**(4):1758–72.
24. Husum H, Gilbert M, Wisborg T, et al. Rural prehospital trauma systems improve trauma outcome in low-income countries: a prospective study from North Iraq and Cambodia. *J Trauma* 2003;**54**(6):1188–96.
25. Gove S, Tamburlini G, Molyneux E, et al. Development and technical basis of simplified guidelines for emergency triage assessment and treatment in developing countries. WHO Integrated Management of Childhood Illness Referral Care Project. *Arch Dis Child* 1999;**81**(6):473–7.
26. Tamburlini G, Di Mario S, Maggi RS, et al. Evaluation of guidelines for emergency triage assessment and treatment in developing countries. *Arch Dis Child* 1999;**81**(6):478–82.
27. Leigh B, Kandeh HB, Kanu MS, et al. Improving emergency obstetric care at a district hospital, Makeni, Sierra Leone: The Freetown/Makeni PMM Team. *Int J Gynaecol Obstet* 1997;**59** (Suppl. 2):S55–65.
28. Mock CN, Quansah R, Addae-Mensah L, et al. The development of continuing education for trauma care in an African nation. *Injury* 2005;**36**(6):725–32.
29. Turner P. Implementation of TeamSTEPPS in the emergency department. *Crit Care Nurs Q* 2012;**35**(3):208–12.
30. Wong EG, Gupta S, Deckelbaum DL, et al. The International Assessment of Capacity for Trauma (INTACT): an index for trauma capacity in low-income countries. *J Surg Res* 2014;**190**(2):522–7.
31. Wesson HK, Bachani AM, Wekesa JM, et al. Assessing trauma care at the district and provincial hospital levels: a case study of hospitals in Kenya. *Injury* 2013;**44**(Suppl. 4):S75–80.
32. Linden AF, Sekidde FS, Galukande M, et al. Challenges of surgery in developing countries: a survey of surgical and anesthesia capacity in Uganda's public hospitals. *World J Surg* 2012;**36**(5):1056–65.
33. Henry JA, Frenkel E, Borgstein E, et al. Surgical and anaesthetic capacity of hospitals in Malawi: key insights. *Health Policy Plan* 2014.
34. Solis C, Leon P, Sanchez N, et al. Nicaraguan surgical and anesthesia infrastructure: survey of Ministry of Health hospitals. *World J Surg* 2013;**37**(9):2109–21.

APPENDIX 10 - BARRIERS TO ESSENTIAL SURGICAL CARE
EXPERIENCED BY WOMEN IN THE TWO NORTHERNMOST
REGIONS OF GHANA: A CROSS-SECTIONAL SURVEY

RESEARCH ARTICLE

Open Access



Barriers to essential surgical care experienced by women in the two northernmost regions of Ghana: a cross-sectional survey

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Abstract

Background: Women in developing countries might experience certain barriers to care more frequently than men. We aimed to describe barriers to essential surgical care that women face in five communities in Ghana.

Methods: Questions regarding potential barriers were asked during surgical outreaches to five communities in the northernmost regions of Ghana. Responses were scored in three dimensions from 0 to 18 (i.e., 'acceptability,' 'affordability,' and 'accessibility'; 18 implied no barriers). A barrier to care index out of 10 was derived (10 implied no barriers). An open-ended question to elicit gender-specific barriers was also asked.

Results: Of the 320 participants approached, 315 responded (response rate 98 %); 149 were women (47 %). Women had a slightly lower barriers to surgical care index (median index 7.4; IQR 3.9–9.1) than men (7.9; IQR 3.9–9.4; $p = 0.002$). Compared with men, women had lower accessibility and acceptability dimension scores (14.4/18 vs 14.4/18; $p = 0.001$ and 13.5/18 vs 14/18; $p = 0.05$, respectively), but similar affordability scores (13.5/18 vs 13.5/18; $p = 0.13$). Factors contributing to low dimension scores among women included fear of anesthesia, lack of social support, and difficulty navigating healthcare, as well as lack of hospital privacy and confidentiality.

Conclusion: Women had a slightly lower barriers to surgical care index than men, which may indicate greater barriers to surgical care. However, the actual significance of this difference is not yet known. Community-level education regarding the safety and benefits of essential surgical care is needed. Additionally, healthcare facilities must ensure a private and confidential care environment. These interventions might ameliorate some barriers to essential surgical care for women in Ghana, as well as other LMICs more broadly.

Keywords: Barriers, Women, Essential surgical care, Ghana, LMIC

Background

Conditions that benefit from timely, safe surgery comprise nearly 16 % of the global disease burden [1]. However, up to five billion people, most of whom live in low- and middle-income countries (LMICs), do not have access to essential surgical care as defined by the world bank's Disease Control Priorities, third edition (DCP-3) [2].

Essential surgical care consists of surgical decision-making and procedures that address high-burden conditions, are cost effective, and are feasible to implement. Given this gap between the burden of surgical conditions and the availability of surgical care services, LMICs have high prevalence of unmet surgical need - a situation where a person has a condition treatable by essential surgical care or is in need of a surgical consultation and is not able to access required care [3, 4]. This is true even for common conditions (i.e. skin and soft tissue masses, breast and gynecological problems) [3, 5].

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The most significant barrier to surgical care in LMICs is inadequate capacity (i.e., infrastructure, human, and physical resources) [6]. While urgently needed, sufficient investment in global surgical care is unlikely to occur in the short term. [7] Therefore, in addition to supporting surgical care development, communities and countries must identify and remove other barriers to surgical care that their populations face in order to significantly reduce the surgical disease burden.

Certain sub-populations, such as women, might be particularly vulnerable to certain barriers that are not significant obstacles for the rest of the population [8]. Therefore, targeted interventions that ameliorate specific barriers may be needed for such sub-populations within a community. Identifying and removing such barriers often represents a cost-effective method for improving the uptake of essential surgery for groups that might have otherwise been excluded from this vital service.

Grimes et al. performed a systematic review of reports that described barriers to surgical care in LMICs [9]. They usefully sorted the barriers identified by the review into 20 themes that represent 3 dimensions: acceptability, affordability and accessibility. However, the review did not return a report that described barriers to essential general surgical care among women in LMICs.

To address this gap, we used this framework to develop a comprehensive tool to assess individual- and community-level barriers to surgical care in LMICs such as Ghana [10]. For this study, we aimed to describe the barriers to surgical care that women face in five particularly deprived communities in northern Ghana and compare them to the barriers faced by men. By doing so, gender-specific barriers could be identified and potential targets for intervention defined.

Methods

Assessment tool

By using a modified Delphi technique we developed the assessment tool by creating questions to represent each of the barriers to surgical care identified by the systematic review by Grimes et al. [9]. Modifications to the Delphi technique included the use of a panel of 5 experts (with experience in developing community-based surveys for LMICs) and not using quantitative methods to include or exclude specific questions for the subsequent round. Instead, the panelists were only given the option of including or excluding the question in the next round, as well as offering questions for the group to evaluate in successive rounds. An initial exploration of potential questions and three survey rounds were used to build consensus on questions that were thought to accurately represent each theme, be relevant for LMICs and be simple to administer. The resultant list of questions was sorted into themes and grouped into

the three dimensions reported by the Grimes et al. review:

- Acceptability – fear and/or mistrust of surgery; marginalized social status; reduced appreciation of medical conditions; degree of their impairment
- Affordability – high direct and/or indirect costs of essential surgical care; lack of social support
- Accessibility – delay in diagnosis; healthcare navigation; structural (i.e., distance and road quality)

Ultimately, 38 barrier-specific questions were included in the tool - four aimed to identify potentially vulnerable sub-populations; 21 represented acceptability; 9 represented accessibility; and 4 represented affordability (Additional file 1). Prior to asking about specific barriers to care, respondents were prompted with: "Which of the following reasons for not having surgery for your problem sooner apply to you?"

At the end of the structured portion of the tool, each patient was prompted to consider and discuss other reasons for not receiving timely surgical care that were not captured by prior questions. Additionally, an open-ended question that aimed to elicit gender-specific barriers not captured by the quantitative section of the tool was included.

Calculating dimension scores and the overall index

Individual dimension scores (i.e., acceptability, affordability, accessibility) were calculated by adding one point for each item that was not a barrier to care. The sum was then multiplied by a dimension factor so that each dimension could have an equal total possible score of 18 points, which would allow apposite comparison. Next, dimension scores were added together. Lastly, the sum of the dimension scores was indexed on a scale from zero to 10, where 10 represented no barriers to surgical care. The resulting index was termed the barriers to surgical care index. Similar indexing methods have been successfully used for surveys of surgical capacity in LMICs [3, 11].

Setting

During a surgical outreach by ApriDec Medical Outreach Group (AMOG), the tool was administered in five communities chosen to represent populations from particularly deprived areas in the northernmost regions (i.e., Upper East and Upper West Regions) of Ghana. AMOG is a Ghanaian-based non-governmental organization (NGO) that performs free surgical outreach after intensive mobilization in areas where significant barriers to surgical care may exist. Sites were purposely sampled to represent rural, peri-urban and urban populations and the regional diversity of surgical capacity. The sites were Nadowli, Nandom, Sandema, Amiah and Bolgatanga. Nadowli, Nandom and Sandema are rural districts with large catchment

areas, no general surgeon and significant resource-deficiencies with regards to surgical care capacity. Amiah and Bolgatanga are peri-urban and urban respectively; have a general surgeon each, but are strained by high demand. Surgical care in each of the sampled sites suffers from baseline physical and human resource deficiencies previously documented in Ghana [12, 13].

Patient sampling and data collection

Community leaders, radio announcements and visually informative flyers in the respective local languages at social activity areas (e.g., churches, mosques, markets) were used to mobilize patients for surgical evaluation several weeks prior to the visit of the outreach team. Patients who presented for evaluation were examined and registered by the hospital staff if they had a potential surgical condition and asked to return during outreach dates.

All patients who presented for surgery were exhaustively sampled. The number of respondents was limited by the effectiveness of the mobilization techniques and the number of operations that the volunteers could perform during the outreach period (i.e., 5 days at each site). Thus, the calculation of a pre-determined sample size and sampling strategy that accurately represented each community was not performed.

At each site, nurses or medical assistants who lived in the respective community and spoke at least one of the local languages were trained as research team members prior to the outreach to ensure adequate skills for conducting interviews and limiting potential interview bias. Team member training focused on interviewing techniques (e.g., questionnaire administration, managing the interview environment and process, active listening, open questioning, reorientation, probing techniques, and response scoring, and ethics) over two days. The tool was translated from English to each of the required local languages and back translated into English to ensure validity of verbal translation by each research team member. After, the assessment tool was verbally administered to each patient in his or her primary language prior to pre-operative preparation to avoid perception contamination that might occur after receiving surgical care (i.e., changing one's mind about surgical care after having received an operation). Women were able to choose between a male and a female interviewer to minimize interviewer-induced bias.

Data analysis

First, the internal consistency and construct validity of the tool were assessed using Cronbach's alpha and confirmatory factor analysis (Additional file 1). For the latter, both the root mean square error of approximation (RMSEA) and coefficient of determination (CD) were calculated.

Second, individual dimension scores and the total barrier to care index for both genders were calculated using Stata v13 (College Station, TX, USA). The Wilcoxon Mann-Whitney test was used to determine whether there was a difference between the barriers to care indices for the two genders. Next, bivariate and three-level mixed effects multivariable logistic regression analysis were performed to determine the effect of being a woman on the odds of having an index in the lowest quartile. The multivariable model included each of the *a priori* defined potentially vulnerable sub-population covariates (i.e., women, children aged less than 18 years, older adults aged more than 50 years, non-literacy, and religious minority). Minors and the elderly were grouped together because of low numbers. The mixed effects model included covariates for region and community to control for intra-class correlation. There was no evidence for significant multicollinearity among the covariates in the model ($1.01 \leq$ variance inflation factor ≤ 1.04). The regression analysis was also performed strictly among women.

Lastly, responses to the qualitative question were analyzed using a content analysis framework [14]. First, responses were grouped into coded categories that represented similar responses. Then, categories were refined into useful themes and described.

Ethics

The Kwame Nkrumah University of Science and Technology Committee for Human Research and Publication Ethics (reference number – CHRPE/AP/391/14), leadership of AMOG, the Regional Health Directorate of the Ghana Health Service and administration of each facility approved the study.

Adults underwent verbal informed consent in the patient's primary language. During the consent process, patients were made aware that participation in the survey had no bearing on their eligibility to receive surgical care. For patients aged less than 18 years, an adult relative supervising the child's hospital stay provided informed consent. Since a child's access to care is dependent on the parents' or guardian's perceptions and means, questions were directed to that person during the assessment, as opposed to the child [15].

Results

Internal consistency and construct validity

Overall, Cronbach's alpha was 0.72, which represents a reasonable degree of internal consistency. Cronbach's alpha values for each of the dimensions demonstrated only moderate reliability: acceptability 0.69; affordability 0.53; accessibility 0.43. Note that the modest values may reflect a lack of inter-relatedness of the barriers to care within each dimension (e.g. fear of surgery and the degree of symptoms

causing impairment of daily work are both listed with the acceptability dimension).

Confirmatory factor analysis revealed evidence for there being a correlation between each question and the dimensions they were supposed to represent, as well as between each dimension and the total barrier index (Additional file 1). The RMSE for the index model was 0.001; the probability of the RMSEA being ≤ 0.05 was 1.00. The index model coefficient of variance was 0.76, which demonstrates reasonable model fit. It should be noted that the number of respondents was smaller than that recommended for a robust confirmatory factor analysis [16]; nonetheless, the results suggest reasonable construct validity.

Demographics and operations

The assessment tool was administered to 310 of the 315 participants approached at the five sites (response rate 98 %). One person refused to participate and four were operated on before being interviewed. The median age was 40 years (range 1–81 years). There were 149 women (47 % of respondents). Most women had no formal education (84, 56 %); median travel time to health facilities was 60 min (IQR 0.2–8 h). There was no evidence for a difference in age, education level, and travel time to the health facility

between women and men. However, women had a longer median duration of surgical condition (48 months; IQR 1–240 months) compared to men (36 months; IQR 2–360; $p = 0.02$). Both women and men most commonly practiced Christianity (77 % and 54 %, respectively). However, more men practiced a traditional religion when compared with women (33 % vs 6 %; $p < 0.001$). Women most commonly presented with a gynecologic problem (54 %) or a goiter (17 %); men most commonly presented with a hernia or hydrocele (75 %) (Table 1).

Barrier dimension scores and index

Women had a statistically significantly lower median barrier to surgical care index (7.4; IQR 3.9–9.1) compared with men (7.9; IQR 3.9–9.4; $p = 0.002$). There was no evidence for a difference in the affordability dimension score between men and women (13.5 out of 18 for both, respectively; $p = 0.13$). However, women had a lower median acceptability dimension score (14.0 out of 18) than men (15.0 out of 18) ($p = 0.05$). Similarly, there was evidence for a difference in the accessibility dimension score between the genders (14.4 out of 18 for both men and women; $p = 0.001$) (Table 2). Although both genders had equal median accessibility scores (14.4 out of 18), women had a lower rank sum value (21,136) than

Table 1 Participant demographic information and operations performed at northernmost regions of Ghana

	Women		Men		Total		p-value
	n	(%)	n	(%)	n	(%)	
Participants	149	(47)	166	(53)	315	(100)	
Age; median (IQR)	38	(16–71)	42	(1–80)	40	(1–80)	0.40
Education completed							
None	84	(56)	102	(62)	187	(59)	0.11
Primary	27	(18)	40	(24)	68	(22)	
Secondary	24	(16)	14	(8)	38	(12)	
More	16	(10)	9	(6)	23	(7)	
Religion							
Christian	114	(77)	88	(54)	204	(65)	<0.001
Traditional	9	(6)	54	(33)	63	(20)	
Muslim	24	(16)	19	(12)	43	(14)	
Other	1	(1)	3	(2)	4	(1)	
Travel time; median min (IQR)	60	(10–480)	60	(5–510)	60	(5–1,441)	0.45
Conditions							
Hernia/hydrocele	18	(12)	124	(75)	142	(45)	<0.001
Goiter	25	(17)	1	(1)	26	(8)	
Skin/soft tissue mass	19	(13)	14	(8)	35	(11)	
Gynecologic problem	80	(54)	8	(5)	88	(28)	
Other	6	(4)	18	(11)	24	(8)	
Duration of problem, median months (IQR)	48	(1–240)	36	(2–360)	36	(1–360)	0.02

IQR interquartile range, mins minutes

Table 2 Barriers to surgical care index and individual dimension scores by gender in the northernmost regions of Ghana

	Total		Women		Men		<i>p</i> -value
	Median	(IQR)	Median	(IQR)	Median	(IQR)	
BSC Index (out of 10)	7.7	(3.6–9.4)	7.4	(3.9–9.1)	7.9	(3.9–9.4)	0.002
Acceptability (out of 18)	14.0	(6.0–18.0)	14.0	7.0–18.0)	15.0	(8.0–18.0)	0.05
Affordability (out of 18)	13.5	(0.0–18.0)	13.5	(0.0–18.0)	13.5	(0.0–18.0)	0.13
Accessibility (out of 18)	14.4	(3.6–18.0)	14.4	(3.6–18.0)	14.4	(7.2–18.0)	0.001

BSC barriers to surgical care, IQR interquartile range

men (28,634) giving large differences in the IQR (women 3.6–18 vs men 7.2–18), implying that they had lower scores (Fig. 1).

There was evidence for women having greater odds of a barrier to care index in the lowest quartile in the bivariate regression model; however, this was not demonstrated by the multivariable model (adjusted OR 1.32; 95%CI 0.72–2.43) (Table 3). Among female respondents only, minors and the elderly and those with no formal education had higher odds of having a barrier to care index in the lowest quartile in both the bivariate or multivariable regression models; however the increase in odds was not statistically significant (Table 4).

Factors contributing to low dimension scores

Figure 2 demonstrates the reported barriers to surgical care by theme. Women more often reported barriers than men for all themes; some examples are worth mentioning. More women reported difficulty in navigating healthcare system compared with men (67; 45 % vs 51; 31 %; $p = 0.04$). Sixty-two women (42 %) reported fear or mistrust of surgical care and 56 (38 %) reported that they felt socially marginalized or were afraid of social stigma regarding their surgical condition. Among men,

these barriers were less frequently reported (54; 33 % and 52; 31 %, respectively). However, there was no evidence for a difference between the genders and these barriers to care ($p = 0.19$ and $p = 0.30$, respectively).

Lack of social support (36 % of women vs 27 % of men; $p = 0.17$), as well as distance to facilities capable of providing essential surgical care (87 % of women vs 81 % of men; $p = 0.25$) were also commonly reported barriers to care.

More women reported having no one to accompany them for surgery and post-operative care compared with men (30; 20 % vs 19; 11 %, $p = 0.03$). Thirty-eight women (26 %) reported not being able to access surgical care because they were not the decision maker in the household and 49 (33 %) reported inordinately long waiting times to get surgical care after referral. The corresponding proportions for men were 16 % and 22 %, respectively ($p = 0.03$). There was a significant difference in the proportion of women (20; 14 %) reporting fear of anesthesia as a barrier to accepting surgical care compared with men (6; 4 %, $p = 0.001$).

Female-specific barriers not captured by the tool

Other barriers offered by women for being unable to access timely surgical care generally fell under the

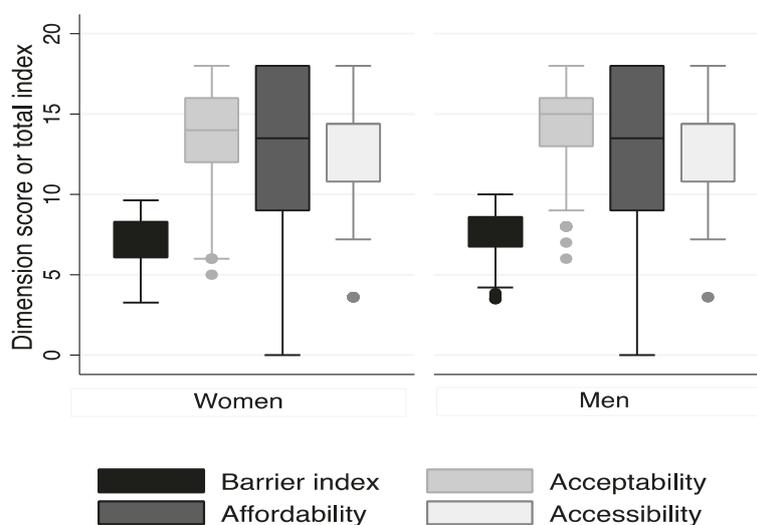


Fig. 1 Box-plot of barriers to surgical care index and individual dimension scores by gender in the northernmost regions of Ghana

Table 3 Odds ratios of having a barrier to care index in the lowest quartile (i.e., most significant barriers to surgical care) in northernmost regions of Ghana

	Odds ratio	(95 % CI)	Adj. odds ratio	(95 % CI)
Sex				
Men	Referent		Referent	
Women	1.92	(1.15–3.24)	1.32	(0.72–2.43)
Age				
18–50 years	Referent		Referent	
Extreme ages ^a	0.75	(0.44–1.28)	0.86	(0.48–1.56)
Education				
None	Referent		Referent	
Any	1.17	(0.69–1.98)	1.23	(0.70–2.18)
Religion				
Christian	Referent		Referent	
Religious minority	0.70	(0.40–1.21)	0.91	(0.49–1.69)

Adj. odds ratio adjusted odds ratio; the multivariate model included each covariate given their a priori potential for representing vulnerable sub-populations, as well as community to control for intra-class correlation. Proportional change in variance = 77 %

^aExtreme ages: <18 years or >50 years

acceptability dimension and included: not trusting health-care personnel to keep their condition and/or surgery confidential and not wanting to expose themselves for examinations in consulting rooms that are often not private enough. The rest were fear of being considered a witch after the community learns that she has a gynecological problem and fear she would be ridiculed for seeking surgical consultation or care in order to get pregnant.

Table 4 Factors affecting a barrier to care index in the lowest quartile (i.e. most significant barriers to surgical care) among women in the northernmost regions of Ghana

	Odds ratio	(95 % CI)	Adj. odds ratio	(95 % CI)
Age				
19–50 years	Referent		Referent	
Extreme ages ^a	1.24	(0.58–2.67)	1.37	(0.57–3.26)
Education				
Any	Referent		Referent	
None	1.38	(0.68–2.79)	1.50	(0.721–3.17)
Religion				
Christian	Referent		Referent	
Religious minority	0.72	(0.31–1.69)	0.77	(0.31–1.87)

Adj. odds ratio adjusted odds ratio; the multivariate model included each covariate given their a priori potential for representing vulnerable sub-populations, as well as community to control for intra-class correlation. Proportional change in variance = 42 %

^aExtreme ages: <18 years or >50 years

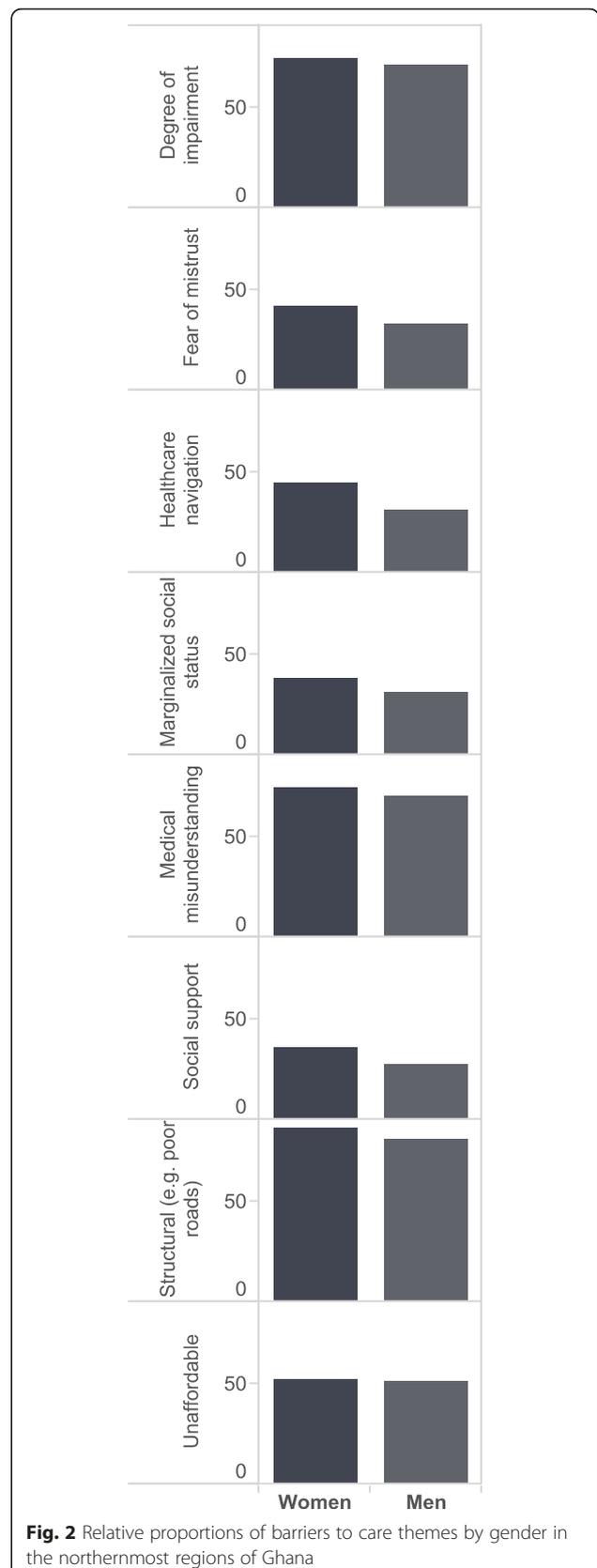


Fig. 2 Relative proportions of barriers to care themes by gender in the northernmost regions of Ghana

Discussion

This study aimed to define barriers to surgical care that women face in five communities in the two northernmost regions of Ghana. While significant barriers to essential surgical care affected both genders, women more often reported barriers than men. This was evidenced by the lower acceptability and accessibility dimension scores among women compared with men, indicating more significant barriers in these areas. Lack of social support, inability to navigate the healthcare system, fear of anesthesia and inadequate privacy were also frequently reported. The disparate indices between genders within the same geographic region highlights the importance of systematically identifying and addressing barriers to care at the community level to improve the uptake of essential surgical care. Despite these differences, there were other barriers for which there was little or no difference between genders. These included some level of misunderstanding about their conditions (e.g. not knowing that a surgical condition can be treated by surgery, seeking cure from traditional healers); structural barriers (e.g., not having personnel capable of performing more than minor procedures, as well as travel distance); and inability to afford essential surgical care.

In their systematic review, Grimes et al. documented barriers to surgical care in LMICs. Their search retrieved reports describing barriers to care for a number of surgical specialties, including ophthalmology, emergency care, and burns. However, there was not a report describing barriers to essential general surgical care among women in LMICs [9]. Nonetheless, the retrieved reports found that distance to health facilities, lack of awareness about the need for surgical intervention for certain conditions, and perceived poor quality of surgical services were among common barriers requiring redress. In addition to these barriers, this study identifies other barriers to general surgical care that include: the influence of other family members on decision-making, fear of anesthesia and/or surgical care, and mistrust of surgical care (i.e. not appreciating the potential benefit and/or safety of surgical care), which should be assessed when trying to develop interventions to improve the uptake of essential surgery in LMICs.

The value of systematically assessing barriers to care at the community level is that, with consideration of local contexts, the results can inform interventions that may improve access to surgical care. For instance, women were more likely to report not having sufficient social support at home or during their hospital stay, which prevented care seeking. In LMICs, surgery is often only available at referral centers, far from patients' homes [17]; the median travel time to health facilities in our study population was 60 min, though it was up to 8 h for some women. Additionally, hospital resource deficiencies mean that many

family members typically shoulder patient care responsibilities (e.g. cleaning, feeding and washing). When women don't have someone to accompany them for surgery, they do not present for care and incur preventable disability or even death [8, 18]. To overcome this barrier, facilities could employ non-healthcare personnel to provide these services or establish a volunteer service, which has been successful in some high-income countries [19]. This barrier could also be overcome by providing more frequent surgical outreaches or temporarily posting a provider capable of essential surgical care in these particularly deprived areas, which might prevent women from having to travel beyond their social support network. Thus, the growing backlog of conditions that incur disability from untreated elective essential surgical conditions might decrease.

Fear of anesthesia was commonly reported as a reason for not seeking surgical care among women. Given similar findings from Turkey, Nigeria and India, this finding is not unique to Ghana [20–22]. Currently, patients scheduled for elective surgery at these facilities are asked to present on the day of their operation and do not get sensitized to the perioperative process beforehand. As a result, patients may have considerable apprehension about anesthesia care. In high-income countries, many surgical services have included a brief, routine pre-anesthesia consultation prior to planned surgery to set expectations and allay fears regarding the perioperative process. Such an encounter might improve the perception of anesthesia among women in communities that are particularly fearful. Further, efforts to incorporate knowledge about anesthesia and surgical care into community-based health promotion initiatives might also be considered.

Privacy and confidentiality are central tenets of medical ethics. However, they have not been prioritized in many LMIC healthcare facilities, which operate above capacity to meet patient demand. As a result, consulting rooms, pre-operative holding areas and wards are often not private enough. While it has been suggested that healthcare privacy is not as valued by LMIC patients as those in high-income countries, this is certainly not the case as our results demonstrate and others have shown [23–27]. All efforts should be made to respect patient privacy and confidentiality by designating private changing areas, draping patients appropriately, using privacy screens and keeping conversations and records confidential [27]. These issues have been identified by studies on patient satisfaction after receiving maternal care services in LMICs [25, 28]. Inadequate privacy during antenatal checkup, lack of confidentiality and being exposed during examination or during delivery were all significant predictors of low satisfaction scores, and in turn, poor compliance and retention [25, 29]. Essential surgical care services might consider incorporating monitoring and evaluation of privacy and

confidentiality into their mandate, which may reduce these barriers to care in the long run.

Several limitations are worth consideration when interpreting these findings. First, the barriers offered by respondents who presented for surgery during the outreach might be different from those that did not present for care. Hospital-based assessments of barriers to surgical care are likely associated with different barriers than those identified by community-based studies [30, 31]. Furthermore, selection bias may also exist as a result of differential response to mobilization efforts between men and women. However, participants in this study were aggressively mobilized from their communities and reported long durations of disease. This group therefore likely represents an adequate intermediate between hospital-based and community-based populations and still provides important barriers that require redress. Second, use of healthcare workers as research team members might have introduced interviewer bias. However, healthcare workers had expertise in structured interpersonal interaction that was useful for rapidly developing the skills required for interviewing. Additionally, they understood the surgical care context within which this study was conducted. These valuable qualities of healthcare workers might moderate the potential interviewer bias rather than create it. Lastly, the assessment tool was designed to identify individual- and community-level barriers to care. Therefore, other important governance and policy barriers may exist that were not measured [8]. However, such issues would likely be reflected, at least in part, by the barriers we identified. Despite these limitations, the results from this study allow reasonable conclusions to be drawn about the barriers to essential surgical care experienced by women in the two northernmost regions of Ghana.

Conclusion

Women in the two northernmost regions of Ghana have more barriers to essential surgical care than their male counterparts. Specific barriers that could be addressed to improve surgical care for people living in these communities, especially among women, include: a lack of social support during hospital stays, fear of anesthesia and inadequate privacy. To improve these barriers, hospitals might consider employing staff or recruiting volunteers to assist women during their hospital stay. Next, there is the need to provide community-specific education to sensitize potentially vulnerable populations about the safety and benefits of essential surgical care where appropriate. Additionally, pre-anesthesia consultations for patients in need of elective surgical care might reduce fears of the perioperative process. Lastly, health facilities should provide a private and confidential environment for all patients, so that they feel respected and safe. In

turn, more people with potentially correctable surgical conditions might present for care. Together, such interventions may significantly improve the uptake of elective essential surgical care in Ghana, as well as other LMICs.

Additional file

Additional file 1: Supplementary material. (DOCX 114 kb)

Abbreviations

AMOG, ApriDec Medical Outreach Group; DCP-3, Disease Control Priorities, third edition; LMIC, low- and middle-income countries; NGO, non-governmental organization

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Availability of data and materials

The dataset will not be shared in order to protect the participants' identity.

Authors' contributions

AG conceived the study, participated in its design and drafted the manuscript. BS conceived the study, participated in the design and participated in data analysis. FA contributed in the study design, supervised data collection and helped with drafting the manuscript. AK contributed in data analysis and critically revised the manuscript for important intellectual content. GB supervised data collection and contributed to analysis of data. AEA supervised data collection and critically revised the manuscript for important intellectual content. SG analysed the data and critically revised the manuscript for important intellectual content. EO helped with study design and critically revised the manuscript for important intellectual content. All authors approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Consent to publish

Not applicable.

Ethics

Ethics approval was granted by The Kwame Nkrumah University of Science and Technology Committee for Human Research and Publication Ethics (reference number – CHRPE/AP/391/14).

Adults underwent verbal informed consent in the patient's primary language. For patients aged less than 18 years, an adult relative supervising the child's hospital stay provided informed consent.

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References

- Alkire BC, Baykar NP, Shrimel MG, Weiser TG, Bickler SW, Rose JA, Nutt CT, Greenberg SL, Kotagal M, Riesel JN et al: Global access to surgical care: a modelling study. *Lancet Global Health*. 2015;3(6):e316–23.
- Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT. Essential surgery: key messages from Disease Control Priorities, 3rd edition. *Lancet*. 2015;385(9983):2209–19.
- Groen RS, Samai M, Stewart KA, Cassidy LD, Kamara TB, Yambasu SE, Kingham TP, Kushner AL: Untreated surgical conditions in Sierra Leone: a cluster randomised, cross-sectional, countrywide survey. *Lancet*. 2012; 380(9847):1082–7.
- Petroze RT, Groen RS, Niyonkuru F, Mallory M, Ntaganda E, Joharifard S, V Estimating operative disease prevalence in a low-income country: results of a nationwide population survey in Rwanda. *Surgery*. 2013;153(4):457–64.
- Stewart BT, Pathak J, Gupta S, Shrestha S, Groen RS, Nwomeh BC, Kushner AL, McIntyre T: An estimate of hernia prevalence in Nepal from a countrywide community survey. *Int J Surg*. 2015;13:111–4.
- Carlson LC, Lin JA, Ameh EA, Mulwafu W, Donkor P, Derbew M, Rodas E, Mkandawire NC, Dhanaraj M, Yangni-Angate H et al: Moving from data collection to application: a systematic literature review of surgical capacity assessments and their applications. *World J Surg*. 2015;39(4):813–21.
- Meara JG, Leather AJ, Hagander L, Alkire BC, Alonso N, Ameh EA, Bickler SW, Conteh L, Dare AJ, Davies J et al. *Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development*. *Surgery*. 2015;158:3–6.
- Irfan FB, Irfan BB, Spiegel DA. Barriers to accessing surgical care in Pakistan: healthcare barrier model and quantitative systematic review. *J Surg Res*. 2012;176(1):84–94.
- Grimes CE, Bowman KG, Dodgion CM, Lavy CB. Systematic review of barriers to surgical care in low-income and middle-income countries. *World J Surg*. 2011;35(5):941–50.
- Stewart BT, Gyedu A, Abantanga F, Abdulai AR, Boakye G, Kushner A. Barriers to essential surgical care in low- and middle-income countries: a pilot study of a comprehensive assessment tool in Ghana. *World J Surg*. 2015;39:2613–21.
- Wong EG, Gupta S, Deckelbaum DL, Razek T, Kamara TB, Nwomeh BC, Haider AH, Kushner AL: The International Assessment of Capacity for Trauma (INTACT): an index for trauma capacity in low-income countries. *J Surg Res*. 2014;190(2):522–7.
- Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, Fleischer-Djoletto C, Moresky R, McCord CW, Cherian M et al: Assessment of capacity for surgery, obstetrics and anaesthesia in 17 Ghanaian hospitals using a WHO assessment tool. *Tropical Med Int Health*. 2010;15(9):1109–15.
- Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, Fleischer-Djoletto C, Moresky R, McCord CW, Cherian M et al: Surgical training and experience of medical officers in Ghana's district hospitals. *Acad Med*. 2011;86(4):529–33.
- Bradley EH, Curry LA, Devers KJ. Qualitative data analysis for health services research: developing taxonomy, themes, and theory. *Health Serv Res*. 2007; 42(4):1758–72.
- Bornstein MH, Britto PR, Nonoyama-Tarumi Y, Ota Y, Petrovic O, Putnick DL. Child development in developing countries: introduction and methods. *Child Dev*. 2012;83(1):16–31.
- Myers ND, Ahn S, Jin Y. Sample size and power estimates for a confirmatory factor analytic model in exercise and sport: a Monte Carlo approach. *Res Q Exerc Sport*. 2011;82(3):412–23.
- Ntirenganya F, Petroze RT, Kamara TB, Groen RS, Kushner AL, Kyamanywa P, Calland JF, Kingham TP: Prevalence of breast masses and barriers to care: results from a population-based survey in Rwanda and Sierra Leone. *J Surg Oncol*. 2014; 110:903–6.
- Filippi V, Richard F, Lange I, Ouattara F. Identifying barriers from home to the appropriate hospital through near-miss audits in developing countries. *Best Pract Res Clin Obstet Gynaecol*. 2009;23(3):389–400.
- Volunteer services, Moran Surgical Center. Utah, USA: Salt Lake City. [http://healthcare.utah.edu/hospital/customer-service/volunteer/opportunities/moran_surgery_center.php]. Accessed 1 Sept 2015.
- Gurunathan U, Jacob R. The public's perception of anaesthesiologists-Indian Attitudes. *Indian J Anaesth*. 2004;48:456–60.
- Osinaike BB, Dairo MD, Oyebamiji EO, Odesanya JO, Tanimowo A. Attitude of general public to risks associated with anaesthesia. *East Afr J Public Health*. 2007;4(1):40–2.
- Sagun A, Birbicer H, Yapici G. Patients', who applied to the anesthesia clinic, perceptions and knowledge about anesthesia in Turkiye. *Saudi J Anaesthesia*. 2013;7(2):170–4.
- Das P, Basu M, Tikadar T, Biswas G, Mridha P, Pal R. Client satisfaction on maternal and child health services in rural bengal. *Indian J Community Med*. 2010;35(4):478–81.
- Jallow IK, Chou YJ, Liu TL, Huang N. Women's perception of antenatal care services in public and private clinics in the Gambia. *Int J Qual Health Care*. 2012;24(6):595–600.
- Nigenda G, Langer A, Kuchaisit C, Romero M, Rojas G, Al-Osimy M, Villar J, Garcia J, Al-Mazrou Y, Ba'aqel H et al: Womens' opinions on antenatal care in developing countries: results of a study in Cuba, Thailand, Saudi Arabia and Argentina. *BMC Public Health*. 2003;3:17.
- Simbar M, Nahidi F, Dolatian M, Akbarzadeh A. Assessment of quality of prenatal care in Shahid Beheshti Medical Science University centers. *Int J Health Care Qual Assur*. 2012;25(3):166–76.
- Srivastava A, Avan BI, Rajbangshi P, Bhattacharyya S. Determinants of women's satisfaction with maternal health care: a review of literature from developing countries. *BMC Pregnancy Childbirth*. 2015;15:97.
- Tetui M, Ekirapa EK, Bua J, Mutebi A, Tweheyo R, Waiswa P. Quality of Antenatal care services in eastern Uganda: implications for interventions. *Pan Afr Med J*. 2012;13:27.
- Balogun OR. Patients perception of quality of antenatal service in four selected private health facilities in Ilorin, Kwara state of Nigeria. *Niger Med Pract*. 2007;51:80–4.
- Bickler S, Ozgediz D, Gosselin R, Weiser T, Spiegel D, Hsia R, Dunbar P, McQueen K, Jamison D: Key concepts for estimating the burden of surgical conditions and the unmet need for surgical care. *World J Surg*. 2010;34(3):374–80.
- Groen RS, Samai M, Petroze RT, Kamara TB, Yambasu SE, Calland JF, Kingham TP, Guterbock TM, Choo B, Kushner AL: Pilot testing of a population-based surgical survey tool in Sierra Leone. *World J Surg*. 2012; 36(4):771–4.

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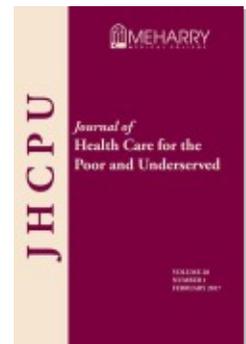
APPENDIX 11 - ASSESSMENT OF BARRIERS TO ESSENTIAL
SURGICAL CARE IN TWO COMMUNITIES IN THE UPPER
WEST REGION, GHANA



PROJECT MUSE®

Assessment of Barriers to Essential Surgical Care in Two Communities in the Upper West Region, Ghana

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Assessment of Barriers to Essential Surgical Care in Two Communities in the Upper West Region, Ghana

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Abstract: Systematic assessments of individual- and community-level barriers to surgical care (BSC) in low- and middle-income countries that might inform potential interventions are lacking. We used a novel tool to assess BSC systematically during a surgical outreach in two communities in Upper West region, Ghana. Results were scored in three dimensions of barriers to care (acceptability, affordability, and accessibility); higher dimension scores signified less salient barriers. A total index out of 10 was derived. In total, 169 individuals participated in Nadowli (68, 40%) and in Nandom (101, 60%). Nadowli had fewer BSC than Nandom (median index 7.8 vs 7.2; $p < .001$). Dimension scores ranged from 10.8 to 14.5 out of 18 points. Fear or mistrust of surgical care and stigma were reported more frequently in Nandom ($p < .001$). Reported barriers were not always the same in each community. Systematically defining barriers to essential surgical care provides an opportunity for planning targeted interventions at the community-level.

Key words: Barriers, essential surgical care, Ghana.

Conditions that benefit from timely, safe surgical care make up nearly 16% of the global disease burden.¹ However, an estimated five billion people may not have access to essential surgical care, the majority of which are in low- and middle-income

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countries (LMICs).² Thus, the prevalence of unmet surgical needs, even for common conditions like hernias, hydroceles, and skin and soft-tissue masses is high in LMICs.³⁻⁵

To address this burden, barriers to essential surgical care must be removed. The greatest barrier to surgical care in LMICs is a lack of capacity (i.e., infrastructure, human, and physical resources).⁶ While urgently needed, it is unlikely that there will be a significant and rapid investment in surgical capacity in the short run.² Therefore, it is equally important to identify and eliminate other barriers to surgical care in LMICs, particularly those that do not require a significant financial investment.

Certain sub-populations (e.g., children, the elderly, women, the un- or under-educated, and religious minorities) might be particularly vulnerable to certain barriers that are not significant obstacles for the majority of the population.⁷ Additionally, specific barriers may differ considerably between communities, as well as individuals within the same community.^{5,7-11} Therefore, efforts to alleviate the effect of specific barriers to surgical care may require interventions specific to different sub-populations in different communities.

In a systemic review of barriers to surgical care in LMICs, Grimes, Bowman, Dodgion et al. identified published barriers and conveniently sorted them into 20 themes, which represented three dimensions. The dimensions were acceptability, affordability, and accessibility.⁸ We used this framework to create and pilot a simple, comprehensive, and flexible tool to assess individual- and community-level barriers to surgical care.

Although there has been a qualitative assessment of barriers to cataract surgery in the Upper East Region of Ghana, there have been no reports published or programs performed that identified barriers to essential general surgical care in communities of the Upper West Region. The Upper West Region is a particularly deprived area in Ghana and in need of significant health improvements.^{12,13} Therefore, we aimed to use the assessment tool to define barriers to surgical care in two communities of the Upper West Region, Ghana, to target future interventions. We also aimed to examine barriers that might not be captured by the tool so that subsequent versions could be improved.

Methods

Assessment tool. The assessment tool was based on a barriers to essential general surgical care framework (Figure 1), adapted from the health care access barriers model described by Carrillo et al.¹⁴ We developed the assessment tool by creating questions from barriers to surgical care identified by the systematic review by Grimes et al. using a modified Delphi technique.⁸ Modifications to the Delphi technique included the use of a smaller than usual number of expert panelists (i.e., five panelists who were Ghanaian health workers and researchers, or public health experts working in Ghana with significant experience in developing and/or administering community-based surveys for LMICs^{3,15,16}) and not using quantitative methods to include or exclude specific questions for the subsequent round. Instead, the panelists were only given the option of including or excluding the question in the next round, as well as offering questions for the group to evaluate in successive rounds. An initial exploration of potential questions and three rounds of questionnaires were used to build consensus on questions

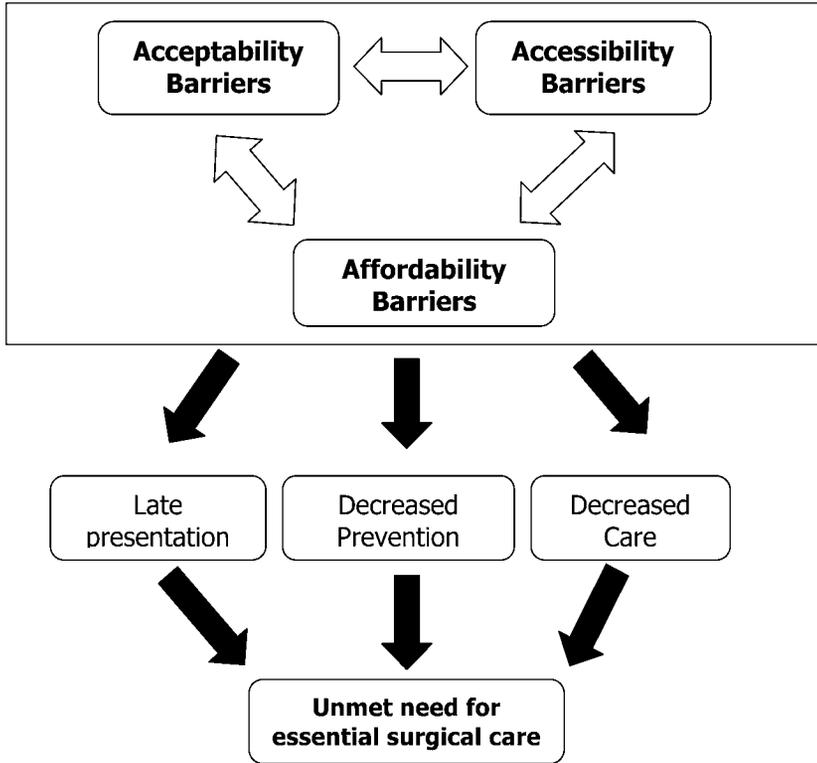


Figure 1. Barriers to essential general surgical care framework.

that were thought to accurately represent each theme, be relevant for LMICs, and be simple to administer.

The resulting list of questions was sorted into themes and grouped into the three dimensions reported by the review (Box 1). Additionally, questions designed to identify potentially vulnerable sub-populations were included. Thirty-eight barrier-specific questions were included in the tool. Four questions aimed to identify potentially vulnerable sub-populations; 21 represented acceptability; nine represented accessibility; and four represented affordability. In addition, the name of the community and basic clinical information about the presenting problem was asked (supplementary material, available from the authors upon request). At the end of the structured portion of the tool, each patient was prompted to consider and discuss other reasons for not receiving timely surgical care not captured by prior questions. The assessment tool was found to be acceptable (26 items, Cronbach's $\alpha = .72$).

Tool scoring. Individual dimension scores (i.e., acceptability, affordability, accessibility) were calculated by adding one point for each item that was not a barrier to care. The sum was then multiplied by a factor in order to give each dimension an equal total possible score of 18 points, which would allow apposite comparison. Next, dimension scores were added together. Finally, the sum of the dimension scores was indexed on a

Box 1.**DIMENSIONS AND THEMES SURROUNDING ESTABLISHED BARRIERS TO SURGICAL CARE INCORPORATED INTO THE ASSESSMENT TOOL⁸**

Dimension	Theme
Acceptability	Fear, mistrust
	Marginalized social status
	Level of medical understanding
	Degree of impairment
Affordability	Direct and indirect costs
	Social support
Accessibility	Transportation difficulty
	Delay in diagnosis
	Structural
	Health care navigation

scale from zero to 10, where 10 represented no barriers to surgical care. The resulting index was termed the barriers to surgical care index. Similar indexing methods have been successfully used for surveys of surgical capacity in LMICs.^{3,17}

Pilot phase. The tool was piloted in Upper East Region, Ghana. It was easy to administer and analyze and it was well accepted by participants (B. Stewart, unpublished data). Given the small pilot sample, the tool required further validation, particularly among more diverse communities, potentially vulnerable sub-populations, and individuals with more varied surgical conditions. Therefore, this study was performed to assess the tool's acceptance among a more diverse population, as well as capture the barriers to essential surgical care they face.

Setting. The tool was administered in two communities chosen to represent populations from a particularly deprived area in Upper West Region, Ghana, during a surgical outreach by ApriDec Medical Outreach Group (AMOG) from 25th to 30th March, 2015. ApriDec Medical Outreach Group is a Ghanaian-based non-governmental organization (NGO) that performs free surgical outreach after substantial community mobilization in areas where surgical care is not readily available. Upper West Region is the most underserved region in Ghana; surgical care capacity is particularly deficient.^{17,18}

The sites were Nadowli and Nandom. Nadowli is 39km from the regional capital, Wa, and has a government-run district-level hospital that is usually staffed by a medical officer (i.e., general practitioner). Nandom is 100km from the regional capital and has a faith-based district-level hospital, which is also staffed by a medical officer. Both hospitals serve populations in surrounding districts that are significantly further from the regional capital, as well as informal populations near the Burkina Faso border. Neither hospital has a general surgeon and both suffer from severe deficiencies in physical and human resources that have been previously documented in Ghana.^{18,19}

Patient sampling and data collection. Community leaders, radio announcements, and visually informative flyers in popular areas (e.g., churches, mosques, markets) were used to mobilize patients for surgical evaluation for two months prior to the outreach. Patients were then examined and registered by the hospital staff if they had a surgical condition and asked to present during outreach dates.

All patients who presented for surgery were exhaustively sampled to participate in the study. The number of respondents was limited by the effectiveness of the mobilization techniques and the logistics of the surgical outreach (i.e., the number of days that the volunteers and research team were available). Therefore, a pre-specified sample size that would accurately represent each community was not possible. Nonetheless, these patients with long-standing untreated surgical conditions who presented only after heavy mobilization can be considered a convenience sample of those with significant barriers to care in the communities who are otherwise hidden.²⁰

At each site, three nurses or medical assistants who lived in the respective community and spoke at least one of the local languages (i.e., Dagare, Sisale, Moshe, Hausa, Wale) were trained as research team members prior to the outreach to ensure adequate skills for conducting interviews while limiting potential interview bias. The tool was translated and back translated into each of the local languages to ensure validity of verbal translation by each research team member. Team member training focused on interviewing techniques (e.g., questionnaire administration, managing the interview environment and process, active listening, open questioning, reorientation, probing techniques, and response scoring) over two days. The assessment tool was administered aloud to each patient in his or her primary language prior to pre-operative preparation to avoid perception contamination that might occur after receiving surgical care (i.e., changing one's mind about surgical care after having received an operation, such as fear of anesthesia, surgery, or post-operative pain). The tool was administered to each patient in private to ensure they were comfortable and relaxed. To ensure anonymity and confidentiality, data identifying the individual were not collected. Data were collected on paper forms and entered at the end of each day in an encrypted electronic database on a password-protected computer. Paper forms were stored in a locked office available only to the principal investigator.

Data analysis. The internal consistency of the tool was assessed with Cronbach's alpha values.

Individual-level barriers to surgical care were described. Categorical variables were reported as frequencies and percentages (e.g., education level) while continuous variables (e.g., age) were reported as median with interquartile ranges. To determine if one or more particularly vulnerable sub-population(s) (minors or the elderly, women, those with no formal education, and religious minorities) had an index in the lowest quartile, bivariate and two-level mixed effects multivariable logistic regressions were performed. Minors were defined as children aged less than 18 years. The elderly were defined as adults aged more than 50 years. The multivariable model included each of the a priori defined potentially vulnerable sub-population covariates (i.e., women, minors and the elderly, the uneducated, and religious minorities). The mixed effects model included the community covariate (i.e., Nadowli, Nandom) to control for intra-class correlation. There was no evidence of significant multicollinearity among the covariates in the

model (variance inflation factor = 1.00). Exploratory stratified analyses did not give evidence for effect modification among the measured covariates.

Community-level barriers to surgical care were described by index and dimension score. The Wilcoxon Mann-Whitney test was used to determine if there was a difference between the barriers to care indices of the two communities.

Responses to the qualitative question were analyzed using a content analysis framework.²¹ First, responses were grouped into categories by codes that represented similar responses. Then, categories were refined into useful themes and described.

Ethics. The Kwame Nkrumah University of Science and Technology Committee for Human Research and Publication Ethics, leadership of AMOG, Regional Health Directorate of the Ghana Health Service, and administration of each hospital approved the study.

Adults underwent spoken informed consent after thorough explanation of the assessment process in the respondent's primary language; an opportunity was provided for each respondent to ask questions related to the study. This process was carried out in private, in a comfortable and relaxed atmosphere. During the consent process, patients were made aware that participation in the survey had no bearing on their eligibility to receive surgical care. Ample time was allowed to answer any questions that patients might have. For patients aged younger than 18 years, an adult relative supervising the child's hospital stay provided informed consent. Since a child's access to care depends on the parents' or guardian's perceptions and means, questions were directed to that person during the assessment, rather than to the child.²²

To ensure anonymity and confidentiality, identifiable data were not collected. As noted above, after each day of data collection, data were transcribed into an encrypted electronic database on a password-protected computer, and the paper forms were stored in a secure office.

While the study had little benefit for the respondents who participated in it, the potential implications for their community were great. For example, the findings might inform ways in which the health care community could reduce the barriers to care for people with a surgical condition.

Results

Internal consistency. Overall, Cronbach's alpha was .72, which represents a reasonable degree of internal consistency. Cronbach's alpha values for each of the dimensions demonstrated only moderate reliability: acceptability .69; affordability .53; accessibility .43. Note that the modest values may reflect a lack of inter-relatedness of the barriers to care within each dimension (e.g., fear of surgery and the degree of symptoms causing impairment of daily work are both listed with the acceptability dimension).

Demographic characteristics and operations. The assessment tool was administered to 169 of the 171 participants approached at the two sites (response rate 99%): Nadowli 68 participants (40%) and Nandom 101 participants (60%). One male refused to participate and one female was operated on before there was a chance to administer the survey; both were in Nandom. The median age was 39 years (range 2–81 years). Most patients were female (114; 67%), had no formal education (90; 53%) and prac-

Table 1.**PARTICIPANT DEMOGRAPHIC INFORMATION AND OPERATIONS PERFORMED AT EACH COMMUNITY IN UPPER WEST REGION, GHANA**

	Nadowli		Nandom		Total	
	n	(%)	n	(%)	n	(%)
Participants	68	(40)	101	(60)	169	(100)
Age; median (IQR) ^a	45	(9–70)	38	(18–78)	39	(5–78)
Male	26	(38)	29	(29)	55	(33)
Education completed						
None	43	(63)	47	(47)	90	(53)
Primary	14	(21)	21	(21)	35	(21)
Secondary	5	(7)	24	(24)	29	(5)
More	6	(9)	9	(9)	15	(4)
Religion						
Christian	49	(72)	85	(84)	134	(79)
Traditional	4	(6)	3	(3)	7	(4)
Muslim	15	(22)	12	(12)	27	(16)
Buddhism	0		1	(1)	1	(1)
Travel time; median mins (IQR)	60	(15–720)	60	(10–240)	60	(10–720)
Conditions						
Hernia/hydrocele	21	(31)	11	(11)	33	(19)
Goiter	13	(19)	5	(5)	18	(11)
Skin/soft tissue mass	11	(16)	16	(16)	27	(16)
Gynecologic problem	18	(27)	59	(59)	77	(46)
Other	5	(7)	10	(10)	15	(8)
Duration of problem, median months (IQR)	48	(9–144)	36	(3–180)	36	(3–240)

^aIQR: interquartile range; mins: minutes.

ticed Christianity (134 participants; 79%), Islam (27; 16%), or a traditional religion (7; 4%) (Table 1).

The median travel time for patients from their home to either Nadowli or Nandom was one hour. However, the travel time interquartile range (IQR) was 10 minutes to six hours, which reflects the rural population and the large catchment area for each hospital. Most patients presented with gynecological problems (77 participants; 46%). However hernias/hydroceles (33 participants; 19%), skin and soft tissues masses (27; 16%), and goiters (18; 11%) were also present. Median duration of condition was 36 months; however, the IQR was three to 240 months, which confirms the presence of significant barriers to essential surgical care (Table 1).

Table 2.**MOST SIGNIFICANT BARRIERS TO SURGICAL CARE AMONG POTENTIALLY VULNERABLE SUB-POPULATIONS OF RESPONDENTS IN UPPER WEST REGION, GHANA**

	Odds Ratio	(95% CI)	Adjusted Odds Ratio	(95% CI)
Age				
18–50 years	Referent		Referent	
Extremes of age ^a	0.65	(0.28–1.51)	0.84	(0.34–2.08)
Sex				
Male	Referent		Referent	
Female	2.50	(1.07–5.84)	2.69	(1.05–6.91)
Education				
Any	Referent		Referent	
None	1.83	(0.89–3.76)	1.87	(0.86–4.06)
Religion				
Christianity	Referent		Referent	
Religious minority ^b	1.05	(0.45–2.45)	0.95	(0.36–2.45)

Notes: The multivariate model included each covariate given their a priori potential for representing vulnerable sub-populations, as well as a covariate representing community to control for intra-class correlation.

^aExtremes of age were defined as <18 years or >50 years.

^bReligious minority was defined as being a Muslim or practicing a traditional religion.

There was evidence for a difference between gender and barrier to care index in the lowest quartile on both the bivariate and multivariable model; females had nearly three times the odds of having an index in the lowest quartile compared with males (adjusted OR 2.69; 95%CI 1.05–6.91). There was no evidence for a predictive relationship between any of the other potentially vulnerable sub-populations (i.e., minors or elders, those with no formal education, religious minorities) and having a barrier to care index in the lowest quartile from the bivariate or mixed effects multivariable regression model (Table 2).

Barriers to surgical care index. Nadowli had fewer barriers to surgical care than Nandom (median index of 7.8; IQR 4.8–9.1 vs 7.2; IQR 4.7–9.0; $p < .001$) (Table 3). The lowest dimension score in Nadowli was affordability (13.5 out of 18), followed by accessibility (14.4 out of 18). Patients in Nandom reported that accessibility was the greatest barrier to care (score 10.8 out of 18). Although dimension scores among patients in Nandom were generally lower than those of Nadowli, there was only evidence for a difference between the two communities for the acceptability dimension ($p < .01$) (Figure 2). For the other dimension scores there was either weak evidence (accessibility score $p = .08$) or no evidence (affordability score $p = .19$) for a difference between the two communities.

Table 3.**BARRIERS TO SURGICAL CARE INDEX AND INDIVIDUAL DIMENSION SCORES IN EACH COMMUNITY IN UPPER WEST REGION, GHANA**

	Nadowli		Nandom	
	median	(IQR) ^a	median	(IQR)
Barrier index	7.8	(4.8–9.1)	7.2	(4.7–9.0)
Acceptability (out of 18)	14.5	(9.0–18.0)	13.0	(7.0–18.0)
Affordability (out of 18)	13.5	(4.5–18.0)	13.5	(4.5–18.0)
Accessibility (out of 18)	14.4	(3.6–14.4)	10.8	(3.6–14.4)

^aIQR: interquartile range.

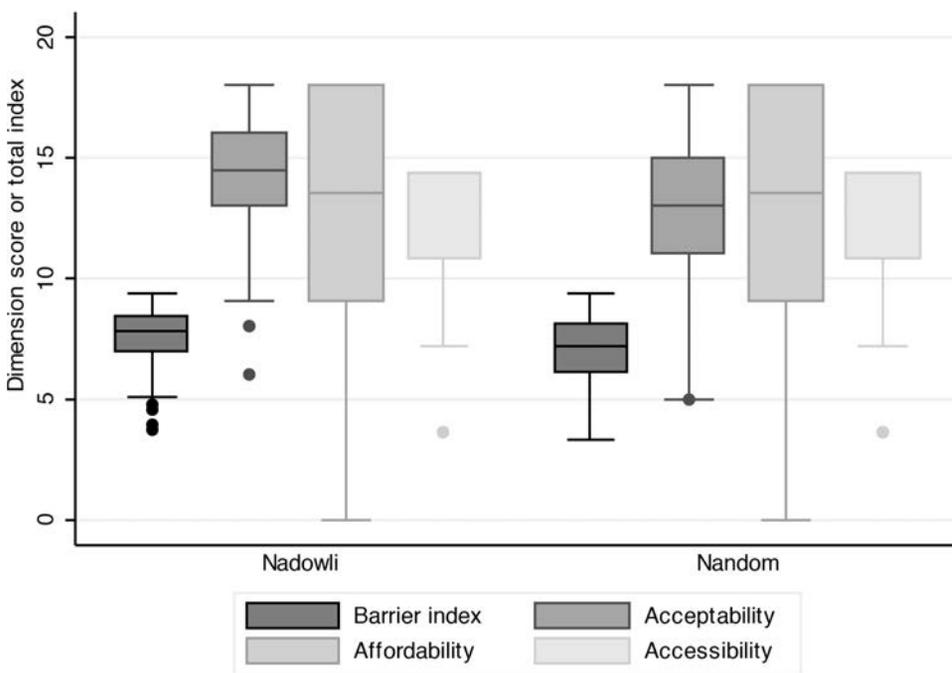


Figure 2. Box-plot of barriers to surgical care index and individual dimension scores in each community in Upper West Region, Ghana.

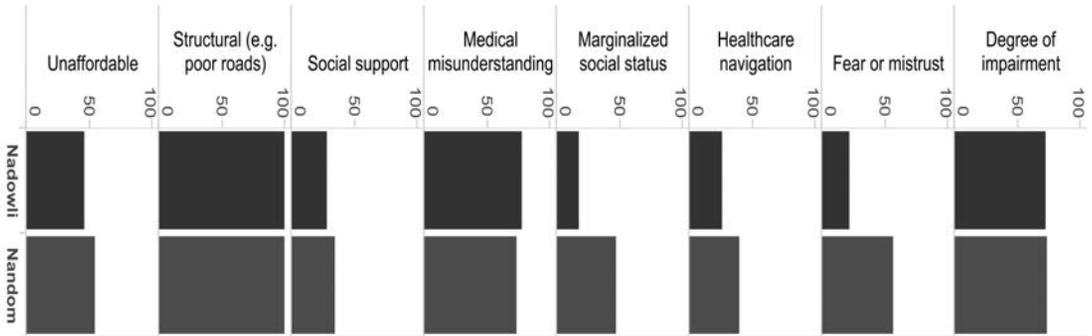


Figure 3. Relative proportions of barriers to care themes in each community in Upper West Region, Ghana.

Factors contributing to low dimension scores. Figure 3 illustrates the barriers to surgical care reported by theme in each community; some examples are particularly revealing. In Nadowli, 22% of respondents reported that fear or mistrust of surgical care was a substantial barrier to care and 18% reported that being of marginalized social status or potential stigma were barriers to care. In Nandom, these barriers were reported much more frequently by respondents (57% and 47% of respondents reported fear or mistrust of surgical care and marginalized social status or potential stigma, respectively [$p < .001$]).

In both Nadowli and Nandom, lack of understanding about surgical conditions (72% and 78% respectively), as well as distance to facilities capable of providing essential surgical care (100% in each community) were commonly reported as barriers to care.

Lack of social support was also an important barrier in both communities (28% of respondents from Nadowli and 35% from Nandom). In Nandom, 55% of respondents reported being unable to afford care compared to 46% in Nadowli ($p = .26$). Specifically, 32 (32%) and 23 (34%) of respondents in Nandom and Nadowli, respectively, reported that direct costs were a barrier to care (i.e., not indirect costs).

Concepts not captured by assessment tool. Other themes respondents offered for not accessing timely surgery included: lack of knowledge about surgical conditions or care and potential social stigma for seeking or having surgery (Box 2). A perception of unsafe or low-quality surgery provided by local facilities was also identified as an important theme. As example, many respondents reported waiting for a surgical outreach to have their problem addressed instead of having surgery performed by local staff because they felt that the outreach was safer or of higher quality.

Discussion

This study aimed to continue to define community-level barriers to surgical care in Ghana, as well as to refine the assessment tool adapted from Grimes et al. By doing so, potential targets for health system strengthening interventions could be proposed and necessary modifications to the assessment tool identified. Individuals in Nandom,

Box 2.

EXAMPLE OF OTHER BARRIERS TO CARE AND RESULTANT THEMES REPORTED BY RESPONDENTS IN UPPER WEST REGION, GHANA

Examples of other reasons given for not having timely surgery	Theme
Unaware that a surgical condition could be cured by surgery (e.g., hernia, goiter)	Insufficient health education for surgical conditions
National Health Insurance Scheme does not prevent hospitals from requesting payment	Fear of costs
Afraid of local health care teams, but would seek care from a national or international NGO ^a	Perception of safety and quality
Did not want operation to be done outside of home town near family, despite not living or working there	Need for social support
Did not trust the surgical team to keep their condition confidential	Fear of identification and stigmatization

^aNGO: non-governmental organization.

with median barrier to care index of 7.2, experienced greater barriers to surgical care compared to those in Nadowli (median barrier to care index of 7.8). Accessibility issues were the most substantial in Nandom while affordability issues were the greatest barriers in Nadowli. Such varying indices for communities within the same region highlight the importance of systematically identifying and addressing barriers to care specific to each community in order to improve uptake of essential surgical care.

The value of systematically assessing barriers to care is that, with consideration of local contexts, the results can inform development of interventions to improve access to essential surgery. For instance, three-quarters of respondents reported some degree of misunderstanding about their conditions (e.g., not knowing that a hernia may lead to an emergency, not knowing that some conditions may be treated by surgery, seeking faith-based cures). Thus, community-based public health education focused on common surgical conditions might improve self-referral and timely surgical care. Given that communities have little exposure to essential surgery, they are often unaware of what benefits surgical care can provide. Therefore, significant efforts need to be made to include health education about essential surgical conditions in local and national community health promotion initiatives.

All respondents reported some aspect of structural barriers to care, such as the facilities not having the requisite personnel to perform the needed procedures, prohibitively long travel distance and/or difficulty navigating the referral and health care system. These barriers could be partly overcome by more adequately resourcing hospitals and/

or providing more frequent surgical outreach to remote communities. Given that there is a lack of investment and resources for surgical care in LMICs, communities like Nandom, which have low accessibility barrier dimension scores can be targeted for improvement first. Additionally, local health care systems (i.e., primary health centers, district-level hospitals, regional referral centers) that have a greater number of respondents reporting difficulties in health care navigation could enlist the help of a steering committee comprised of community-members, health care workers and health system administrators that works to identify these challenges and overcome them to improve timely access to surgical care for their catchment area. In Ghana, a similar committee structure was charged with creating a Kangaroo Mother Care strategy for low-birth weight infants for four regions.²³ With both community and health care participants, the committee was able to develop and successfully implement the strategy in 26 of the 38 target communities. Resultantly, maternal uptake of the practices was high and outcomes improved. The power of including both community and health care stakeholders when developing or strengthening services with a community-hospital interface, such as elective essential surgery, should not be underestimated.

A third of respondents in each community mentioned inability to afford essential surgical care. Most of the patients presented with conditions that should be covered under the Ghana National Health Insurance Scheme (NHIS). The NHIS was set up in 2003 to cover over 95% of disease conditions that affect Ghanaians, including those that require essential surgery.²⁴ Despite early success, total timely reimbursement rates are now low due to reliance on a narrow tax base and a large informal sector, as well as greater than expected health care utilization.^{25–27} As a result, hospitals are often unable to purchase consumables, generator fuel and hire ancillary staff.²⁸ Therefore, hospitals may be transferring payment back on patients to finance basic care. This presents an opportunity to advocate for a less fragile NHIS structure that reliably covers essential care of all types, including safe surgery and anesthesia.

Respondents reported other barriers that are not well discussed in the surgical literature from LMICs. For example, respondents reported potential stigmatization associated with having certain surgical conditions (e.g., fibroids that contribute to infertility). In Nepal almost a third of respondents to a community-based survey who had hernias reported that potential stigma was a significant barrier to surgical care.⁵ Similarly, focus group discussions in Sierra Leone demonstrated that the fear of stigma regarding scarring, loss of a body part, and no longer being a “whole person” was common and often un-reported.²⁹ Stigma is a complex theme that requires a greater understanding in order to develop useful interventions to minimize its effect on access to essential surgical care.

Limitations. There are several limitations worth considering when interpreting these findings. First, the barriers reported by participants having surgery with the outreach might be different from those faced by people who did not receive surgery. Hospital-based assessments of barriers to surgical care may be associated with different barriers than those found by community-based studies.^{30,31} Further, selection bias may also exist as a result of differential response to mobilization efforts between men and women, or those with specific barriers to care (e.g., fear or mistrust). However, participants in this study were aggressively mobilized from their communities and reported long durations of disease. Therefore, this group likely represents an adequate

intermediate between hospital-based and community-based populations without the resource and time expenditures associated with large population-based studies. Nonetheless, individuals who did not present for care likely face more significant barriers to care than those who did. Second, use of health care workers as research team members might have introduced interviewer bias. However, health care workers had expertise in structured interpersonal interaction useful for rapidly developing the skills required for interviewing (e.g., active listening, redirection, and probing techniques) and understood the surgical care context within which this study was conducted. These valuable qualities of health care workers might moderate the potential interviewer bias rather than create it. Further, health care workers from the respective community health system were not used (in order to avoid social response bias). Lastly, the assessment tool was designed to identify individual- and community-level barriers to care. Therefore, other important governance and regulation barriers may exist that were not measured.⁷ Nonetheless, these barriers would likely affect the acceptability, accessibility, or affordability of care. Despite these limitations, the results from this study allow reasonable conclusions to be drawn about the presence of significant barriers to surgical care in Upper West Region, Ghana.

Implications. Community-specific barriers to surgical care that could be improved in Upper West Region include sensitizing communities to the potential benefits of essential surgical conditions and care (e.g., hernias, breast masses, goiters, fibroids) and reducing the time that these facilities are without a surgical care provider. Further, there is a need to understand more fully the reasons women have greater barriers to surgical care than men, as well as the stigma that surrounds surgical conditions and care. In addition, as capacity improves, it will be important to improve patient confidence in the local surgical care system, especially in Nandom.

The next step is to identify communities that would benefit most from a deeper understanding of local barriers to surgical care, such as those with high surgical disease burden or for communities that have adequate surgical capacity and a lower than expected surgery case rate. For such areas it would be important to understand and address non-resource-related barriers that prevent patients from receiving timely essential surgical care. Ultimately, it is important to develop ways in which specific barriers to care might be reduced to improve access to safe, timely, and affordable essential surgical care.

Conclusion. The assessment tool was well accepted, easily administered, and provided useful data for planning targeted interventions at the community-level. Reported barriers were not necessarily the same in each community. Thus systematically defining community-specific barriers to essential surgical care provides an opportunity for planning targeted interventions at the community level.

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Conflict of interest

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. Lozano R, Naghavi M, Foreman K, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012 Dec 15;380(9859):2095–128. [http://dx.doi.org/10.1016/S0140-6736\(12\)61728-0](http://dx.doi.org/10.1016/S0140-6736(12)61728-0)
2. Meara JG, Leather AJ, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Surgery*. 2015 Jul;158;100(6):12–5.
3. Groen RS, Samai M, Stewart KA, et al. Untreated surgical conditions in Sierra Leone: a cluster randomised, cross-sectional, countrywide survey. *Lancet*. 2012 Sep 22;380(9847):1082–7. Epub 2012 Aug 14. [http://dx.doi.org/10.1016/S0140-6736\(12\)61081-2](http://dx.doi.org/10.1016/S0140-6736(12)61081-2)
4. Petroze RT, Groen RS, Niyonkuru F, et al. Estimating operative disease prevalence in a low-income country: results of a nationwide population survey in Rwanda. *Surgery*. 2013 Apr;153(4):457–64. Epub 2012 Dec 17. <http://dx.doi.org/10.1016/j.surg.2012.10.001> PMID:23253378
5. Stewart BT, Pathak J, Gupta S, et al. An estimate of hernia prevalence in Nepal from a countrywide community survey. *Int J Surg*. 2015 Jan;13:111–4. <http://dx.doi.org/10.1016/j.ijssu.2014.12.003> PMID:25500564 PMCID:PMC4323996
6. Carlson LC, Lin JA, Ameh EA, et al. Moving from data collection to application: a systematic literature review of surgical capacity assessments and their applications. *World J Surg*. 2015 Apr;39(4):813–21. <http://dx.doi.org/10.1007/s00268-014-2938-8> PMID:25566980
7. Irfan FB, Irfan BB, Spiegel DA. Barriers to accessing surgical care in Pakistan: healthcare barrier model and quantitative systematic review. *J Surg Res*. 2012 Jul;176(1):84–94. Epub 2011 Aug 27. <http://dx.doi.org/10.1016/j.jss.2011.07.046> PMID:22079839
8. Grimes CE, Bowman KG, Dodgion CM, et al. Systematic review of barriers to surgical care in low-income and middle-income countries. *World J Surg*. 2011 May;35(5):941–50. <http://dx.doi.org/10.1007/s00268-011-1010-1> PMID:21360305
9. Hodge A, Byrne A, Morgan A, et al. Utilisation of health services and geography: deconstructing regional differences in barriers to facility-based delivery in Nepal. *Matern Child Health J*. 2015 Mar;19(3):566–77. <http://dx.doi.org/10.1007/s10995-014-1540-x> PMID:24927787
10. Maslove DM, Mnyusiwalla A, Mills EJ, et al. Barriers to the effective treatment and prevention of malaria in Africa: a systematic review of qualitative studies. *BMC Int Health Hum Rights*. 2009 Oct 25;9:26.

- <http://dx.doi.org/10.1186/1472-698X-9-26>
PMid:19852857 PMCID:PMC2782321
11. Phillips KA, Morrison KR, Andersen R, et al. Understanding the context of healthcare utilization: assessing environmental and provider-related variables in the behavioral model of utilization. *Health Serv Res.* 1998 Aug;33(3 Pt 1):571–96.
PMid:9685123 PMCID:PMC1070277
 12. Atuoye KN, Dixon J, Rishworth A, et al. Can she make it? Transportation barriers to accessing maternal and child health care services in rural Ghana. *BMC Health Serv Res.* 2015 Aug 20;15:333.
<http://dx.doi.org/10.1186/s12913-015-1005-y>
PMid:26290436 PMCID:PMC4545969
 13. Biritwum RB, Mensah G, Minicuci N, et al. Household characteristics for older adults and study background from SAGE Ghana Wave 1. *Global Health Action.* 2013 Jun 11;6:20096.
<http://dx.doi.org/10.3402/gha.v6i0.20096>
PMid:23759325 PMCID:PMC3681208
 14. Carrillo JE, Carrillo VA, Perez HR, et al. Defining and targeting health care access barriers. *J Health Care Poor Underserved.* 2011 May;22(2):562–75.
<http://dx.doi.org/10.1353/hpu.2011.0037>
PMid:21551934
 15. Gupta S, Ranjit A, Shrestha R, et al. Surgical needs of Nepal: pilot study of population based survey in Pokhara, Nepal. *World J Surg.* 2014 Dec;38(12):3041–6.
<http://dx.doi.org/10.1007/s00268-014-2753-2>
PMid:25189447
 16. Stewart BT, Lafta R, Esa Al Shatari SA, et al. Fall injuries in Baghdad from 2003 to 2014: results of a randomised household cluster survey. *Injury.* 2016 Jan;47(1):244–9. Epub 2015 Nov 14.
<http://dx.doi.org/10.1016/j.injury.2015.11.006>
PMid:26626808
 17. Wong EG, Gupta S, Deckelbaum DL, et al. The International Assessment of Capacity for Trauma (INTACT): an index for trauma capacity in low-income countries. *J Surg Res.* 2014 Aug;190(2):522–7. Epub 2014 Feb 4.
<http://dx.doi.org/10.1016/j.jss.2014.01.060>
PMid:24594216
 18. Choo S, Perry H, Hesse AA, et al. Assessment of capacity for surgery, obstetrics and anaesthesia in 17 Ghanaian hospitals using a WHO assessment tool. *Trop Med Int Health.* 2010 Sep;15(9):1109–15. Epub 2010 Jul 14.
<http://dx.doi.org/10.1111/j.1365-3156.2010.02589.x>
 19. Choo S, Perry H, Hesse AA, et al. Surgical training and experience of medical officers in Ghana's district hospitals. *Acad Med.* 2011 Apr;86(4):529–33.
<http://dx.doi.org/10.1097/ACM.0b013e31820dc471>
PMid:21346502
 20. Caton S, Greenhalgh F, Goodacre L. Evaluation of a community dental service for homeless and 'hard to reach' people. *Br Dent J.* 2016 Jan 22;220(2):67–70.
<http://dx.doi.org/10.1038/sj.bdj.2016.56>
PMid:26794111
 21. Bradley EH, Curry LA, Devers KJ. Qualitative data analysis for health services research: developing taxonomy, themes, and theory. *Health Serv Res.* 2007 Aug;42(4):1758–72.
<http://dx.doi.org/10.1111/j.1475-6773.2006.00684.x>

- PMid:17286625 PMCID:PMC1955280
22. Bornstein MH, Britto PR, Nonoyama-Tarumi Y, et al. Child development in developing countries: introduction and methods. *Child Dev.* 2012 Jan-Feb;83(1):16–31. <http://dx.doi.org/10.1111/j.1467-8624.2011.01671.x>
PMid:22277004 PMCID:PMC3412563
 23. Bergh AM, Manu R, Davy K, et al. Progress with the implementation of kangaroo mother care in four regions in Ghana. *Ghana Med J.* 2013 Jun;47(2):57–63. PMid:23966740 PMCID:PMC3743115
 24. National Health Insurance Scheme (NHIS). Benefits package. Accra, Ghana: NHIS, 2015. Available at: <http://www.nhis.gov.gh/benefits.aspx>.
 25. Lagomarsino G, Garabrant A, Adyas A, et al. Moving towards universal health coverage: health insurance reforms in nine developing countries in Africa and Asia. *Lancet.* 2012 Sep 8;380(9845):933–43. [http://dx.doi.org/10.1016/S0140-6736\(12\)61147-7](http://dx.doi.org/10.1016/S0140-6736(12)61147-7)
 26. McIntyre D, Garshong B, Mtei G, et al. Beyond fragmentation and towards universal coverage: insights from Ghana, South Africa and the United Republic of Tanzania. *Bull World Health Organ.* 2008 Nov;86(11):871–6. <http://dx.doi.org/10.2471/BLT.08.053413>
PMid:19030693 PMCID:PMC2649570
 27. Sodji-Tettey S, Aikins M, Awoonor-Williams JK, et al. Challenges in provider payment under the Ghana National Health Insurance Scheme: a case study of claims management in two districts. *Ghana Med J.* 2012 Dec;46(4):189–99. PMid:23661837 PMCID:PMC3645172
 28. Stewart BT, Quansah RE, Gyedu A, et al. Strategic assessment of trauma care capacity in Ghana. *World J Surg.* 2015;39(10):2428–40. <http://dx.doi.org/10.1007/s00268-015-3132-3>
PMid:26154575
 29. Groen RS, Sriram VM, Kamara TB, et al. Individual and community perceptions of surgical care in Sierra Leone. *Trop Med Int Health.* 2014 Jan;19(1):107–16. Epub 2013 Nov 8. <http://dx.doi.org/10.1111/tmi.12215>
PMid:24304743
 30. Bickler S, Ozgediz D, Gosselin R, et al. Key concepts for estimating the burden of surgical conditions and the unmet need for surgical care. *World J Surg.* 2010 Mar;34(3):374–80. <http://dx.doi.org/10.1007/s00268-009-0261-6>
PMid:19862570 PMCID:PMC2816802
 31. Groen RS, Samai M, Petroze RT, et al. Pilot testing of a population-based surgical survey tool in Sierra Leone. *World J Surg.* 2012 Apr;36(4):771–4. <http://dx.doi.org/10.1007/s00268-012-1448-9>
PMid:22311139

APPENDIX 12 - THE BIRTH AND GROWTH OF THE NATIONAL AMBULANCE SERVICE IN GHANA



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The Birth and Growth of the National Ambulance Service in Ghana

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Abstract

Introduction—This study aimed to document the growth and challenges encountered in the decade since inception of the National Ambulance Service (NAS) in Ghana, West Africa. By doing so, potentially instructive examples for other low- and middle-income countries (LMICs) planning a formal prehospital care system or attempting to identify ways to improve existing emergency services could be identified.

Methods—Data routinely collected by the Ghana NAS from 2004–2014 were described, including: patient demographics, reason for the call, response location, target destination, and times of service. Additionally, the organizational structure and challenges encountered during the development and maturation of the NAS were reported.

Results—In 2004, the NAS piloted operations with 69 newly trained emergency medical technicians (EMTs), nine ambulances, and seven stations. The NAS expanded service delivery with 199 ambulances at 128 stations operated by 1,651 EMTs and 47 administrative and

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maintenance staff in 2014. In 2004, nine percent of the country was covered by NAS services; in 2014, 81% of Ghana was covered. Health care transfers and roadside responses comprised the majority of services (43%–80% and 10%–57% by year, respectively). Increased mean response time, stable case holding time, and shorter vehicle engaged time reflect greater response ranges due to increased service uptake and improved efficiency of ambulance usage. Specific internal and external challenges with regard to NAS operations also were described.

Conclusion—The steady growth of the NAS is evidence of the need for Emergency Medical Services and the effects of sound planning and timely responses to changes in program indicators. The way forward includes further capacity building to increase the number of scene responses, strengthening ties with local health facilities to ensure timely emergency medical care and appropriateness of transfers, assuring a more stable funding stream, and improving public awareness of NAS services.

Keywords

developing countries; Emergency Medical Services; Ghana

Introduction

Emergency conditions are responsible for a disproportionately large burden of disease in low- and middle-income countries (LMICs).¹ Inopportunistly, patients in LMICs lack access to timely care for common conditions that require emergency treatment.² As a result, the avertable burden of conditions requiring emergency care is enormous and requires a robust, multi-faceted approach to be reduced.^{2,3} While hospital-based emergency care improvement initiatives are important in this effort, their absolute effectiveness is limited by significant prehospital times and a large proportion of people who die before reaching the hospital in LMICs.^{4,5}

In Ghana, West Africa, prehospital emergency care services were entirely informal and extremely limited prior to the early 2000s.^{6,7} Resultantly, more than one-half of seriously injured patients died prior to reaching a hospital, even in urban centers, compared to 21% in Seattle, Washington USA.⁸ The majority of severely ill or injured people who reached a health facility were brought there by a commercial vehicle (eg, taxi or minibus), often only after relatives paid commercial drivers for their service.⁵ Such practices sometimes included some form of first aid, usually carried out without any formal training. In addition to prehospital care needs, inter-hospital transfers for diagnostics or more advanced treatments are common given limited hospital-based care capacity at first- and second-level hospitals in Ghana, as they are in other LMICs.^{9,10} Without a formal ambulance service, inter-hospital transfers often involved a taxi, pre-payment, and long delays in care associated with families' attempts to gather money.^{6,11} Further, medical care capabilities provided during transport were non-existent. For these reasons, a more formal prehospital care system urgently was required.

In an effort to improve the weak de-facto prehospital care system, courses that provided first aid training to commercial drivers were established and demonstrated some success.⁶ However, no organized, systematic strategy for their sustainability over the long-term was

developed; thus, over time, they were dissolved.^{6,7} Similarly, a few health administrators and political leaders attempted to found prehospital care capabilities in several areas by providing ambulances directly to hospitals.¹¹ Without planning for the training of staff to use them, re-stocking of supplies, ongoing monitoring, and evaluation or formal financing mechanisms, these systems ultimately failed also.¹¹

On May 9, 2001, 127 people were trampled to death at a stadium disruption in Accra, Ghana, which was reported to the public in dramatic detail. In part due to a newfound public awareness of a deficient disaster management strategy and part the effect of long-term advocacy by health professionals, a groundswell of support for an ambulance system began. During the following Annual Sessional Address to Parliament, Ghana's head of state, His Excellency John Agyekum Kufour, charged the Ministry of Health (Accra, Ghana) and collaborators to establish a national ambulance service.¹¹ As a result of this directive and the immense efforts of officers in the health sector, the National Fire Service (Accra, Ghana), the Office of the State Attorney (Accra, Ghana), and others, the National Ambulance Service (NAS) was established in 2004 and became fully operational in 2006.

This study aimed to document the growth and challenges encountered in the decade since the creation of the NAS in Ghana. The examples might be instructive for other LMICs planning the foundation of a formal prehospital care system or attempting to identify ways to improve existing prehospital care services.

Methods

Setting

Ghana is a heavily indebted, lower-middle income country in West Africa with a population of 26 million and an annual per capita income of US\$1,760.¹² While 53% of the population live in one of several densely populated areas, 12.2 million are spread over 348,540 km².¹³ Only 13% of the country's 109,515 km of roads are paved, which are of varying quality. As proxies for conditions requiring emergency transport, injuries and obstetric emergencies are responsible for 45 and nine deaths per 100,000 persons per year, respectively.¹⁴ Figures from an equivalently sized high-income country, the United Kingdom, are used for reference: 82% live in urban areas; 100% of roads are paved with a total network of 398,350 km².¹⁵ There are 36 injury deaths per 100,000 persons annually. Obstetric emergency deaths are rare (0.1 per 100,000 persons).¹⁴

Nearly all of the 216 districts in Ghana have a first-level hospital that is staffed by a general practitioner and provides basic emergency and surgical services (eg, assessment, resuscitation, and cesarean section);¹⁶ however, many first-level staff have insufficient emergency care training.¹⁷ Further, these facilities often are limited by a lack of human and/or physical resources, which limits their capabilities for more advanced care (eg, diagnostic imaging and general laboratory services).^{18–20} Patients that require more complex care are referred to a higher level hospital (ie, one of the nine referral hospitals or four tertiary hospitals); the NAS often performs these transfers so that care can be rendered during transport. Referral and tertiary hospitals have specialist providers and offer a greater scope of emergency services and definitive care.

Data Collection

Organizational structure and specific challenges were described in narrative based on prior documentation and the experiences of the authors who work for the NAS.^{21,22} Additionally, data routinely collected by the NAS were used. After each ambulance response, patient demographics, reason for the call, location of response, and times associated with each part of service delivery were recorded. Data were entered into a database daily and reviewed weekly by station supervisors for accuracy and completeness. After, data were transmitted to NAS headquarters in Accra for archiving and periodic evaluation.

Each data item was not collected for every year since NAS inception. As the ambulance service matured and operational needs changed, certain data items were dropped and others added. Therefore, some data were not recorded for certain years (eg, indicator times for 2004). These gaps are specified in the tables. Use of these routinely gathered, anonymous data for this publication was determined to be exempt from review by the University of Washington (Seattle, Washington USA) Institutional Review Board.

Indicator Definitions

Response time is the time from reception of the call by station personnel to time at the patient's side. Case holding time is the time from arriving at the patient's side to leaving the health care facility or scene with the patient. Vehicle engaged time is the total time spent per call, from reception of the call to ready for the next call, including completion of documentation and sanitizing and re-stocking the ambulance.

Data Analysis

Descriptive statistics were performed with Stata v13 (College Station, Texas USA). Station locations were geo-referenced and maps were created using ArcGIS v10 (Redlands, California USA). Coverage representations on the map were generated assuming that, on average, 60km could be covered realistically in one hour from each station given the diversity of road quality, average traffic density, and improved mobility with siren use. Polygons were drawn to represent areas within 200 meters of a primary, secondary, or tertiary road (ie, roads that ambulances are able to traverse safely). Areas were calculated excluding bodies of water. As a gross proxy for unmet prehospital care need, the responses per day per population were calculated using population estimates from the World Bank Group (Washington, DC USA).¹³ The rates were calculated using available data; therefore, they are not disaggregated by station or region.

Results

Creating an Organizational Structure

With proposal of the NAS Bill in 2004, seven sites in three of Ghana's 10 regions were selected to pilot the NAS. Fifty-seven members of the National Fire Service and six drivers were trained as emergency medical technicians (EMTs). These personnel staffed the pilot stations for 15 months. Managing these pilot sites unearthed significant challenges related to lack of direct oversight that led the creation of a three-tiered organizational structure.

The first tier was the National Headquarters, which is made up of permanent Ministry of Health staff who are charged with: (1) national and regional operational and financial oversight; (2) policy formation; (3) monitoring and evaluation; (4) purchasing and procurement; (5) human resource development; (6) training and education; (7) management of information systems; and (8) research (Figure 1). Each region has a coordinator, usually a medical officer (ie, medical doctor without specialist training), who liaises between the Regional Health Service (Accra, Ghana), National Fire Service, and Headquarters. In addition, the Regional Medical Coordinator provides medical oversight and supports station operations to ensure quality service delivery. The operational level is the individual station. The EMTs work under a lead EMT and in close collaboration with the District Fire Officers, since they often share infrastructure (eg, station facilities).

Initially, two control rooms, located in the two most populous cities, responded to calls on the emergency access telephone line and dispatched ambulances from individual stations as appropriate. To meet increasing demand, the NAS has expanded to nine control rooms around the country. This multi-tiered structure has allowed the NAS to grow rapidly while maintaining quality control mechanisms at both the operation level (ie, stations) and within the organization as a whole.

Infrastructure Development

In 2004, the NAS piloted operations with 69 newly trained EMTs, nine ambulances, and seven stations. After the pilot phase demonstrated operational success, the number of EMTs, ambulances, stations, and employees nearly were tripled (Table 1). Save the training of more EMTs, this level of input was maintained until 2012. During the same year, the government was able to increase funding for the NAS, which allowed development of a stand-alone EMT training program, purchase of 100 ambulances, and creation of 97 additional stations. The EMT school used a curriculum that was co-developed by EMT instructors from the North Dakota Army National Guard (Bismarck, North Dakota USA) and experts within the NAS; the curriculum was based on the principles of Basic Life Support, Prehospital Trauma Life Support (PHTLS), and other fundamental prehospital care topics (eg, recognition and care of medical and obstetric emergencies, as well as emergency medical systems operations). The curriculum prepares trainees for the cognitive and psychomotor exams offered for EMT certification by the United States National Registry of Emergency Medical Technicians (NREMT; Columbus, Ohio USA). Additionally, the NAS established continuous professional development education opportunities that allowed EMTs to advance their accreditations from basic EMT to advanced EMT. In 2008, there were no advanced EMTs. Currently, the ratio of advanced to basic EMTs is one to eight, respectively. Since the EMT training school's formation, nearly 2,000 EMTs have been trained.

Rapid station expansion in 2012 relied on use of existing infrastructure, such as fire stations, municipal buildings, and district hospitals. However, given space constraints at fire stations and the need to be proximate to hospitals, stand-alone and hospital-based stations were developed preferentially.

To oversee and maintain effective operations with this level of input, the NAS required an additional 27 administrative and maintenance employees. However, this still was not

sufficient. The EMTs and staff were working excessive hours; coordination and ambulance and station maintenance were lacking. In 2012, the demand for EMTs was great enough to open a formal and self-sustaining EMT school.

Therefore, the NAS continued to train EMTs and recruit staff to meet the demands (1,698 total employees in 2014). As a result of these efforts, the percent of the country's land covered by the NAS has increased from nine percent in 2004 to 33% in 2008 to 81% in 2014 (Figure 2). Additionally, these changes have improved EMT work hours. The EMTs currently work two 12-hour day shifts, two 12-hour night shifts, and then have two days off.

Services Provided

The number of responses increased from 205 in 2004 to 1,598 in 2005 without a change in inputs (eg, EMTs, ambulances, or stations; Table 2). Instead, public and health care provider promotion of the emergency access telephone number and NAS services through television and radio shows and direct-to-provider advertising (eg, hospital visits and brochures) increased demand. After 2006, the number of responses relatively was constant and constrained by the number of staff, ambulances, and stations. With the addition of the inputs described above in 2012, the number of responses more than doubled: 7,810 in 2012; 17,204 in 2013; and 20,236 in 2014.

The majority of patients cared for by the NAS were between 15 and 55 years of age (58%–84% by year after 2006; Table 2). However, older adults (ie, those >55 years of age) comprised between nine percent and 30% of responses, and infants (ie, children less than one year of age) accounted for five percent to 13% of responses by year since 2006. Most responses were to health care facilities for inter-hospital transfer (43%–80% by year), followed by the roadside (10%–57% by year; Figure 3). Although the numbers of scene responses (eg, residences, schools, and places of work) have increased, the majority of responses were to health care facilities for all years except 2004.

Despite an increase in the absolute number of NAS responses, utilization remained relatively constant: 0.3 responses per ambulance per day in 2006; 0.5 in 2009; and 0.3 in 2014 (not tabled). However, the responses per day per 100,000 population increased across the study period consistent with NAS growth: 0.06 in 2006; 0.07 in 2009; and 0.21 in 2014 (not tabled).

Monitoring and Evaluation System

Response, case holding, and vehicle engaged times have been monitored by the NAS since the pilot phase for monitoring and evaluation of efficiency, quality, and coverage. In the pilot phase, mean response time was 13.1 minutes (SD = 0.18) and mean vehicle was engaged was 200.4 minutes (SD = 0.31; Table 3). Response times generally increased to 19.5 minutes in 2014 (SD = 0.02). This was related, in part, to the greater uptake of the single-access emergency telephone number by individuals and health care facilities, leading to greater travel distances. Nonetheless, gains in efficiency were evidenced by a 10% decrease in the vehicle engaged time to 180.3 minutes (SD = 0.32) in 2014.

The above results highlight specific examples and challenges related to the growth of the NAS. Table 4 presents a synthesis of past, current, and future directions of the NAS more generally for each of the 14 components of an ambulance service.²³

Discussion

This report documents the growth of the NAS in the first decade of operations in Ghana. Since completion of the pilot phase in 2006, the NAS has refined an effective organizational and oversight structure, developed an EMT training school, increased its number of responses four-fold, and maintained an active monitoring and evaluation system. However, several challenges remain and require innovative strategies and sustained efforts addressing them moving forward.

Other LMIC Successful Ambulance Systems

Ambulance services can significantly reduce morbidity and mortality of patients with emergency conditions.²⁴ However, few LMICs have developed and implemented a formal prehospital care system due to lack of political will, sufficient capital, local advocacy, and/or strategic planning.²⁵ Another example of a successful prehospital care model in a LMIC is the Green Cross ambulance service in Monterey, Mexico.⁴ This was a small ambulance service in the mid-1990s with only two stations and medics with limited training. In response to the significant unmet emergency care need with the ambulance service structure at the time, the Green Cross increased the number of stations to four and strategically placed them around the city to minimize response times in 1997. Around the same time, Spanish-language PHTLS was provided semi-annually to all of the Green Cross medics. A subsequent analysis of these improvements demonstrated that the response time nearly halved. Further, successful use of spinal immobilization, airway rescue maneuvers, and fluid resuscitation increased and prehospital mortality decreased from 10% to seven percent.⁴ The cost of doubling of the number of stations and providing semi-annual PHTLS training to medics was US\$75,000 and US\$77,600, respectively. These significant improvements only accounted for 16% of the Green Cross annual budget, despite more than doubling its capabilities. Similar improvements in LMIC prehospital care services have been reported in Trinidad and Pakistan.^{26,27}

Several challenges encountered from the Rescue 1122, the Pakistan government-run fire, rescue, disaster response, and ambulance service, are particularly informative. Rescue 1122 relied on local manufacturing benchmarked by international standards for building their ambulance fleet, saving an estimated US\$25.6 million on import costs.²⁷ To avoid the capital costs required to create a de novo training platform, they used the Elite Police Training School (Lahore, Pakistan) until they were able to secure infrastructure for a permanent training facility. Additionally, Rescue 1122 constructed ambulance stations based on response times rather than target populations, allowing more people to be served with fewer resources. This is a useful model for many LMICs with poor road infrastructure, significant traffic congestion in urban and peri-urban areas, and limited respect for emergency sirens. Importantly, all of the services ran by Rescue 1122 (ie, fire, rescue, disaster response, and ambulance) were supervised by a single command structure to avoid confusion among

response teams during mass causality or disaster situations when communication breakdown is a significant potentiality. Lastly, critical incident reviews and response times were used to monitor and evaluate the effect of program interventions and its growth. These lessons can be condensed: develop within the local context; build on existing infrastructure; and systematically monitor and evaluate the system to inform quality or efficiency improvement initiatives.

Ghana NAS Building on Existing Infrastructure

Similar to the Green Cross and Rescue 1122, the lack of qualified EMTs to fill open positions in the rapidly growing ambulance service was a significant challenge. Prior to NAS creation, there was not an EMT training program in the country. For the pilot program, Fire Service members were recruited and trained as EMTs jointly by the Ministry of Health and the National Fire Service. As the NAS and demand for specialized EMTs grew, the Ministry of Health took over recruiting and training from an open applicant pool, though still using National Fire Service facilities. Opening of the stand-alone EMT training school in 2012 significantly increased the number of qualified EMTs and allowed simultaneous expansion in the number of ambulances and stations to better meet the population's prehospital care demand. In countries without formal EMT training programs, this staged approach and reliance on existing infrastructure may be a useful strategy while plans for training capacity improvements take shape.

Ghana NAS Monitoring and Evaluation

Having learned lessons from previous attempts at developing local or regional ambulance services in Ghana, the NAS was committed to routinely collect, collate, and examine data to monitor and evaluate operational efficiency and the quality of care provided. For each run, EMTs record data that capture the nature of the call (ie, simple demographics, location of scene, and reason for call), care provided, and destination. Indicator times were added in 2005. Station supervisors and Headquarters staff habitually review these data. This database allows monitoring of trends in service utilization and identification of outlier stations that are in need of quality improvement or that are models of successful operations. By doing so, the NAS can better plan training and expansion priorities and adapt services to changing demands. As an example of database use to target priorities for NAS expansion, it was noticed that improvements in mean response and case holding times from 2006 through 2008 were stalled in 2009. After focused discussions with station and Regional Medical Coordinators, it was realized that the rate-limiting factor for improving response times was the number of vehicles currently in operation. With these data, the NAS was able to lobby the Government of Ghana for funds to expand their fleet. At the end of 2012, 100 vehicles were purchased. Resultantly, the number of cases responded to more than doubled in less than one year.

Remaining Challenges and Opportunities for Improved Service Delivery

Despite increases in prehospital capacity, NAS utilization has remained relatively low (0.3 responses per ambulance per day in 2014). For comparison, estimates from other countries, regardless of national income, range from two to 20 responses per ambulance per day varying by rural/urban locale and funding mechanism.²⁸⁻³¹ These figures are difficult to

compare directly since the NAS utilization rate includes all ambulances, regardless of functionality, and published rates may only include functional ambulances “on duty.” To give a gross estimate of unmet prehospital care need, the number of responses per day per 100,000 population range from 6.0 in Shenzhen, China to 46.7 in New South Wales, Australia, compared to 0.2 in Ghana.^{32,33} Some possible explanations for low NAS utilization rates and/or significant unmet prehospital care need include: prohibitively expensive health care costs that prevent patient transfers;¹⁹ insufficient knowledge of the role of the NAS or emergency access telephone number among the population; frequent need for vehicle servicing and/or repair; and population growth that is exceeding NAS expansion.

Similar to other LMIC prehospital services, the greatest challenge faced by NAS remains insufficient funding to meet the prehospital care needs of the growing population.²⁵ Although the NAS Bill allowed creation the NAS in 2004, it has not been ratified by Parliament. Thus, the funding scheme is ad hoc, namely from remaining Ministry of Health funds. With ratification, two significant changes will occur: (1) dedicated and planned funding for NAS activities; and (2) a regulatory mandate for the NAS to supervise, standardize, and coordinate all ambulance services nationwide.

Emergency Medicine recently has become an accredited specialty in Ghana.³⁴ Two hospitals have Emergency Medicine training programs, one in the south and one in the north. These institutions are important stakeholders in the development of the NAS, particularly with regard to developing protocols aimed at improving the rate at which critically ill or injured patients receive necessary care (eg, destination triage and pre-arrival instructions). Additionally, graduates of these programs who complete fellowships in prehospital/disaster medicine will be important partners in the research the NAS undertakes, as well as its medical direction.

There are several externalities that challenge efficient NAS operations. These include: frequent false alarms and inappropriate inter-hospital transfers;³⁵ lack of street names and house numbers; disrespect of sirens by motorists; and occasional health care facility refusal of emergency cases. While the NAS has attempted to sensitize both the population and health care facility staff, more progress must be made to mitigate some of the aforementioned challenges.

Conclusion

Despite the challenges faced, the steady growth and uptake of NAS services is evidence of both the significant need for Emergency Medical Services and sound operational and financial planning. Several of the challenges faced and solutions employed to overcome them are particularly useful, such as: creating an organizational structure that easily permits information exchange from stations to Headquarters and maintains constant administrative and medical oversight; identifying the need for an EMT training school and systematically escalating educational resources to meet the growing demand; and making routine data collection, monitoring, and evaluation a routine part of daily operations. Notwithstanding duteous effort by the NAS, all of the aforementioned activities have been made possible by

sustained political commitment, which will be made concrete by the ratification of the NAS Bill.

Abbreviations

EMT	emergency medical technician
LMICs	low- and middle-income countries
NAS	National Ambulance Service
PHTLS	Prehospital Trauma Life Support

References

1. Lozano R, Naghavi M, Foreman K, et al. Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012; 380(9859):2095–2128. [PubMed: 23245604]
2. Stewart B, Khanduri P, McCord C, et al. Global disease burden of conditions requiring emergency surgery. *Br J Surg*. 2014; 101(1):e9–22. [PubMed: 24272924]
3. Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT. Essential surgery: key messages from Disease Control Priorities. *Lancet* (3rd). 2015; 385(9983):2209–2219. [PubMed: 25662414]
4. Arreola-Risa C, Mock CN, Lojero-Wheatly L, et al. Low-cost improvements in prehospital trauma care in a Latin American city. *J Trauma*. 2000; 48(1):119–124. [PubMed: 10647576]
5. Forjuoh S, Mock C, Freidman D. Transport of the injured to hospitals in Ghana: the need to strengthen the practice of trauma care. *Prehosp Immediate Care*. 1999; 3:66–70.
6. Mock CN, Tiska M, Adu-Ampofo M, Boakye G. Improvements in prehospital trauma care in an African country with no formal EMS. *J Trauma*. 2002; 53(1):90–97. [PubMed: 12131396]
7. Tiska MA, Adu-Ampofo M, Boakye G, Tuuli L, Mock CN. A model of prehospital trauma training for lay persons devised in Africa. *Emerg Med J*. 2004; 21(2):237–239. [PubMed: 14988361]
8. Mock C, Jurkovich G, Amon-Kotei D. Trauma mortality patterns in three nations at different economic levels: implications for global trauma system development. *J Trauma*. 1998; 44(5):804–814. [PubMed: 9603081]
9. Quansah R, Mock C, Abantanga F. Status of trauma care in Ghana. *Ghana Med J*. 2004; 38:149–152.
10. Crandon IW, Harding HE, Williams EW, Cawich SO. Inter-hospital transfer of trauma patients in a developing country: prospective descriptive study. *Int J Sur*. 2008; 6(5):387–391.
11. Mock, C., Juillard, C., Joshipura, M., Goosen, J. *Strengthening Care for the Injured: Success Stories and Lessons Learned from Around the World*. Geneva, Switzerland: World Health Organization; 2010.
12. United States Central Intelligence Agency. CIA World Factbook. 2014. <http://www.ciaworldfactbook.us/africa/ghana.html>. Accessed April 12, 2015
13. World Bank Group. Ghana. 2015. <http://data.worldbank.org/country/ghana>. Accessed January 14, 2015
14. Institute of Health Metrics and Evaluation. Data Visualizations: Global Burden of Disease Cause Patterns. <http://vizhub.healthdata.org/gbd-cause-patterns/>. Accessed May 27, 2015
15. World Bank Group. United Kingdom and Great Britain. 2014. <http://www.worldbank.org/en/country>. Accessed May 6, 2015
16. Stewart BT, Quansah R, Gyedu A, et al. Serial assessment of trauma care capacity in Ghana in 2004 and 2014. *JAMA Surg*. 2016; 151(2):164–171. [PubMed: 26502036]

17. Rominski S, Bell SA, Yeboah D, Sarna K, Hartney H, Oteng R. Skills and educational needs of accident and emergency nurses in Ghana: an initial needs analysis. *African J Emerg Med.* 2011; 1(3):119–125.
18. Ankomah J, Stewart BT, Oppong-Nketia V, et al. Strategic assessment of the availability of pediatric trauma care equipment, technology, and supplies in Ghana. *J Pediatr Surg.* 2015; 50(11): 1922–1927. [PubMed: 25841284]
19. Stewart BT, Quansah R, Gyedu A, Ankomah J, Donkor P, Mock C. Strategic assessment of trauma care capacity in Ghana. *World J Surg.* 2015; 39(10):2428–2440. [PubMed: 26154575]
20. Japiong KB, Asiamah G, Owusu-Dabo E, et al. Availability of resources for emergency care at second-level hospital in Ghana: a mixed methods assessment. *African J Emerg Med.* 2016; 6(1): 30–37.
21. Mock C, Abantanga F, Goosen J, Joshipura M, Juillard C. Strengthening care of injured children globally. *Bull World Health Organ.* 2009; 87(5):382–389. [PubMed: 19551257]
22. National Ambulance Service. Accra: Ghana Ministry of Health; 2009.
23. National Transportation Safety Administration. *Emergency Medical Systems: Agenda for the Future.* Washington, DC USA: US National Transportation Safety Administration; 1996.
24. Ryyanen OP, Irola T, Reitala J, Palve H, Malmivaara A. Is Advanced Life Support better than Basic Life Support in prehospital care? A systematic review. *Scand J Trauma Resusc Emerg Med.* 2010; 18:62. [PubMed: 21092256]
25. Razzak JA, Kellermann AL. Emergency medical care in developing countries: is it worthwhile? *Bull World Health Organ.* 2002; 80(11):900–905. [PubMed: 12481213]
26. Ali J, Adam RU, Gana TJ, Bedaysie H, Williams JL. Effect of the Prehospital Trauma Life Support (PHTLS) program on prehospital trauma care. *J Trauma.* 1997; 42(5):786–790. [PubMed: 9191657]
27. Waseem H, Naseer R, Razzak JA. Establishing a successful prehospital emergency service in a developing country: experience from Rescue 1122 service in Pakistan. *Emerg Med J.* 2011; 28(6): 513–515. [PubMed: 20844094]
28. Kobusingye, OC., Hyder, AA., Bishai, D., Joshipura, M., Hicks, ER., Mock, C. *EMS: Disease Control Priorities in Developing Countries.* Washington, DCUSA: World Bank, Group; 2006.
29. Prinja S, Bahuguna P, Lakshmi PV, et al. Evaluation of publicly financed and privately delivered model of emergency referral services for maternal and child health care in India. *PLoS One.* 2014; 9(10):e109911. [PubMed: 25360798]
30. Cowell, J. *Review of Operations of Ground Emergency Medical Services in Alberta.* Alberta, Canada: Health Care Quality Council of Alberta; 2013.
31. Terzi O, Sisman A, Canbaz S, Dundar C, Peksen Y. A geographic information system-based analysis of ambulance station coverage area in Samsun, Turkey. *Singapore Med J.* 2013; 54(11): 653–658. [PubMed: 24276104]
32. Man Lo S, Min Yu Y, Larry Lee LY, et al. Overview of the Shenzhen Emergency Medical Service call pattern. *World J Emerg Med.* 2012; 3(4):251–256. [PubMed: 25215072]
33. New South Wales Government. *Ambulance services of New South Wales; Australia: 2014.* <http://www.nsw.gov.au>. Accessed June 22, 2015
34. Martel J, Oteng R, Mould-Millman NK, et al. The development of sustainable emergency care in Ghana: physician, nursing, and prehospital care training initiatives. *J Emerg Med.* 2014; 47(4): 462–468. [PubMed: 25066956]
35. Gyedu A, Baah EG, Boakye G, Ohene-Yeboah M, Otupiri E, Stewart BT. Quality of referrals for elective surgery at a tertiary care hospital in a developing country: an opportunity for improving timely access to and cost-effectiveness of surgical care. *Int J Surg.* 2015; 15:74–78. [PubMed: 25659222]

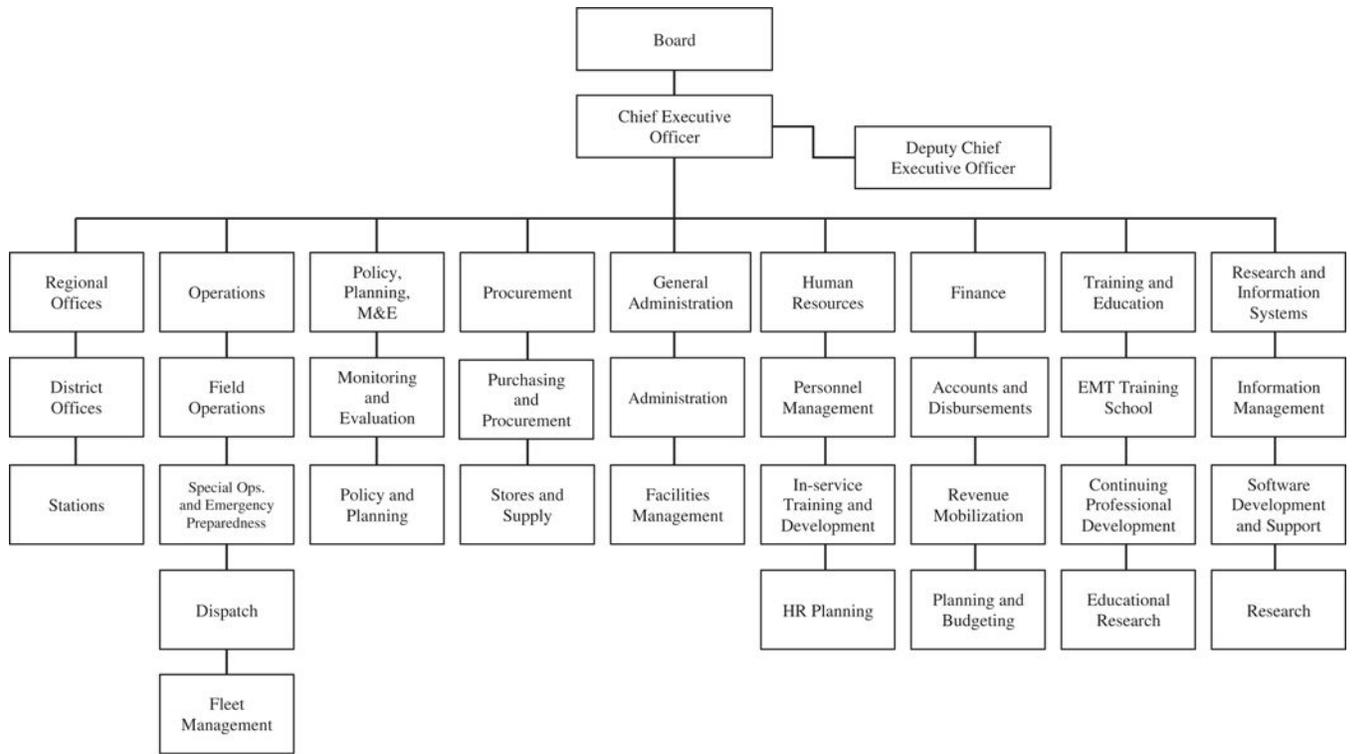


Figure 1.
 Ghana National Ambulance Service Organogram.
 Abbreviations: EMT, emergency medical technician; HR, human resources; M&E, monitoring and evaluation; Ops, operations.

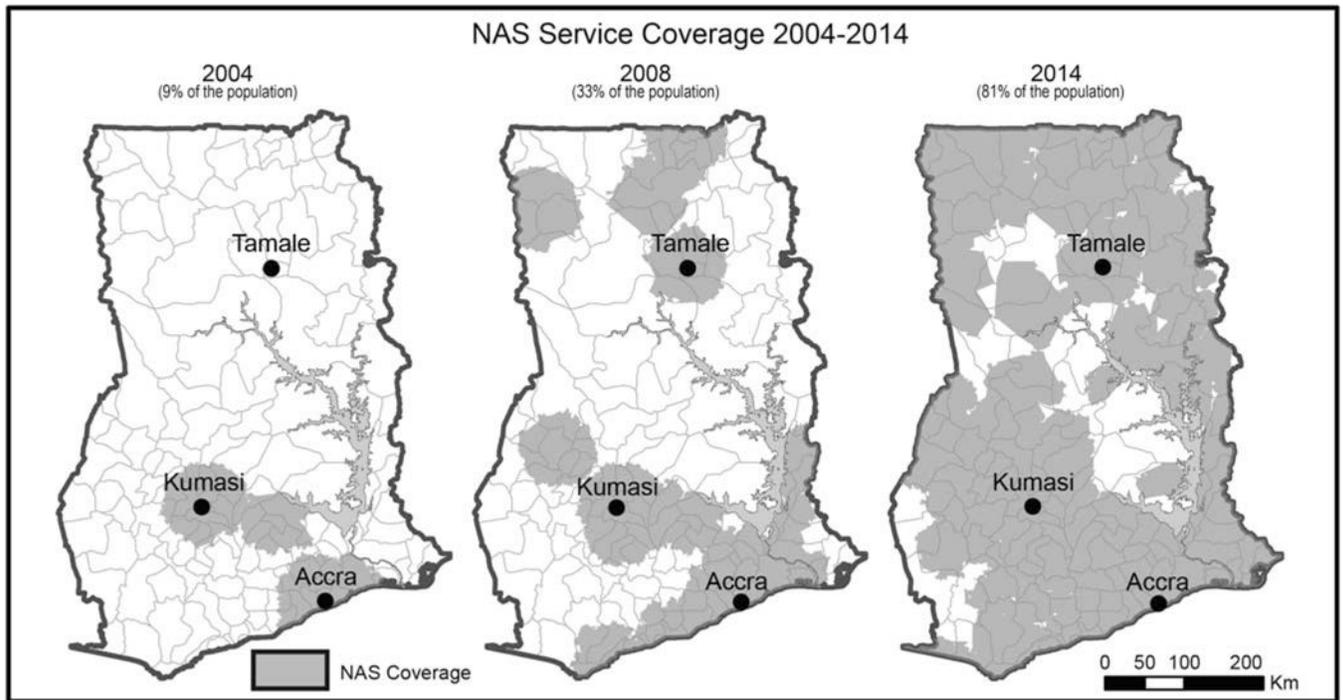


Figure 2.
Map of the Expansion of Service Range by the National Ambulance Service in Ghana from 2004 through 2014.

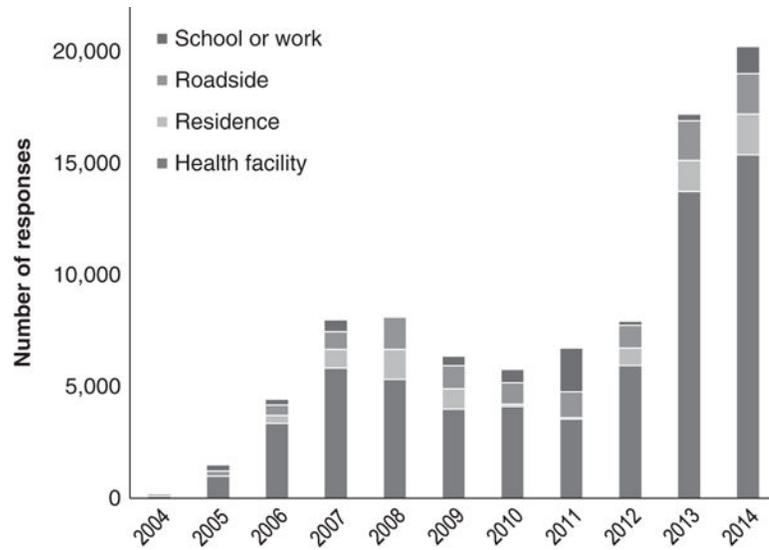


Figure 3.
Number and Location of Responses by the National Ambulance Service in Ghana from 2004 through 2014.
Note: Health facility refers to inter-hospital transfer for referral or diagnostic evaluation.

Table 1
Infrastructure and Capacity of the National Ambulance Service in Ghana from 2004 through 2014

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
National Population (millions)	20.8	21.4	22.0	22.5	23.1	23.7	24.3	24.9	25.6	26.2	26.8
Number of EMTs	69	66	176	228	221	220	220	202	673	911	1,651
Number of Ambulances	9	9	37	37	37	37	38	99	199	199	199
Number of Stations	7	7	24	24	24	24	24	24	121	122	128
Total Employees	69	71	182	232	225	230	228	228	700	956	1,698

Abbreviation: EMT, emergency medical technician.

Table 2

Characteristics of Patients Cared for by the National Ambulance Service in Ghana from 2004 through 2014

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total Patients	205	1,498	4,442	7,995	8,114	6,368	5,252	4,760	7,810	17,204	20,236
Age											
< 1 year	0 (0)	20 (1)	560 (13)	380 (5)	253 (3)	545 (9)	245 (5)	342 (7)	390 (5)	1,000 (6)	1,826 (9)
1–14 years	0 (0)	99 (7)	457 (10)	434 (5)	348 (4)	678 (11)	515 (10)	395 (8)	139 (2)	1,149 (7)	1,681 (8)
15–20 years	140 (68)	480 (32)	777 (17)	1,754 (22)	1,235 (15)	1,009 (16)	437 (8)	986 (21)	2,025 (26)	2,361 (14)	11,775 (58)
21–55 years	65 (32)	612 (41)	1,998 (45)	4,676 (58)	5,010 (62)	3,149 (49)	3,067 (59)	2,150 (45)	4,531 (58)	7,600 (44)	2,515 (12)
≥ 56 years	0 (0)	287 (19)	650 (15)	751 (9)	1,268 (16)	987 (15)	968 (19)	887 (19)	725 (9)	5,094 (30)	2,439 (12)
Sex											
Male	99 (48)	489 (33)	2,230 (50)	4,478 (56)	4,597 (57)	2,258 (35)	2,498 (48)	2,384 (50)	3,782 (48)	8,072 (47)	9,201 (45)
Female	106 (52)	1,009 (67)	2,212 (50)	3,517 (44)	3,517 (43)	4,110 (65)	2,734 (52)	2,376 (50)	4,028 (52)	9,132 (53)	11,035 (55)
Condition											
Medical	205 (100)	887 (59)	1,283 (29)	5,234 (65)	4,589 (57)	2,989 (47)	3,000 (57)	2,870 (60)	3,798 (49)	6,345 (37)	8,802 (43)
Trauma	0 (0)	611 (41)	1,363 (31)	1,332 (17)	1,734 (21)	1,564 (25)	573 (11)	1,560 (33)	1,320 (17)	4,562 (27)	5,639 (28)
Obstetric	0 (0)	0 (0)	920 (21)	895 (11)	1,000 (12)	1,345 (21)	1,028 (20)	200 (4)	1,123 (14)	4,577 (27)	4,877 (24)
Investigation ^a	0 (0)	0 (0)	876 (20)	534 (7)	791 (10)	470 (7)	631 (12)	130 (3)	1,569 (20)	1,720 (10)	918 (5)

^aTransfer refers to referral from one health care facility to another for the purpose of obtaining diagnostic evaluation that is not available at the initiating facility or escalation of care.

Table 3
Indicator Times for the National Ambulance Service in Ghana from 2004 through 2014

	2005 ^a	2006	2007	2008	2009	2010	2011	2012	2013	2014
	mean (SD)	mean (SD)	mean (SD)	mean (SD)	mean (SD)	mean (SD)	mean (SD)	mean (SD)	mean (SD)	mean (SD)
Run Time (min)										
Response Time ^b	13.1 (0.18)	13.2 (0)	12.6 (0.01)	12.5 (0.02)	20.0 (0.04)	17.4 (0.04)	18.7 (0.20)	17.1 (0.02)	17.4 (0.05)	19.5 (0.02)
Case Holding Time ^c	20.2 (0.04)	18.6 (0)	21.0 (0.03)	13.5 (0.03)	17.7 (0.50)	15.5 (0.04)	18.6 (0.04)	17.0 (0.10)	18.3 (0.01)	20.3 (0.03)
Vehicle Engaged Time ^d	200.4 (0.31)	203.1 (0)	164.8 (0.24)	128.0 (0.34)	155.8 (0.20)	178.8 (0.23)	178.8 (0.05)	188.1 (0.04)	185.4 (0.13)	180.3 (0.32)

^aData from 2004 were not available for inclusion.

^bResponse time – time from call received to arrival at the scene/facility.

^cCase holding time – time from arrival at the scene/facility to leaving scene/facility with patient.

^dVehicle engaged time – total time that vehicle is used for a single response.

Table 4

Evolution and Future Directions of the NAS in Ghana since 2004

EMS Component	Past and Present	Future
Integration of Health Services	Ad hoc transfer of patients to nearest facility; limited communication with facility regarding incoming patients.	Selective transfer to capable health facilities based on patient acuity; standardize communication to receiving facilities regarding incoming patients; integrate the care of seriously ill and injured persons with the new emergency medicine training programs.
EMS Research	Capacity assessment and advocacy research; establishment and staffing of a research department.	Defining access to care gaps; identifying ways to improve NAS service uptake; supporting the research department efforts to improve NAS care and EMS care in LMICs more broadly.
Legislation and Regulation	NAS Bill drafted and proposed to Parliament.	Ratification of NAS Bill, which will increase NAS scope from service delivery to regulation of all ambulances services nationwide.
System Finance	Inconsistent/insufficient funding, namely the result of delay in NAS Bill ratification.	Dedicated funding after ratification of NAS Bill.
Human Resources	Reliance on cross-trained staff with National Fire Service; steady expansion of EMT pool after opening EMT school.	Keep pace with demand; strategic increase in numbers of EMT-As to provide more advanced care during transport.
Medical Direction	Regional medical coordination; insufficient funds and expertise to finance local medical direction.	Provide medical direction at the sub-regional level; performance evaluation; develop a pool of emergency medicine physicians in prehospital care management.
Education Systems	Combined education with National Fire Service; opening of EMT school.	Provide continuing education for EMTs and medical directors.
Public Education	Television and radio shows regarding NAS services and potential benefits of prehospital care.	Community-based first aid and prehospital care promotion campaigns.
Prevention	Television and radio shows regarding ways to prevent injury.	Join efforts with other national and non-governmental organizations that participate in injury and disease prevention initiatives.
Public Access	Multiple emergency access telephone numbers for: NAS, National Fire Service, and Police Service; creation of public relations department.	Single emergency access telephone number for all safety and security services.
Communication Systems	Telephone-based sub-national communication system for dispatch; toll-free access telephone numbers now recognized by all mobile communication service providers.	Single shared call center for all national safety and security services; standardize communication regarding incoming patients between ambulances and hospitals.
Clinical Care	Single level of EMT was expanded to basic and advanced levels.	Increase availability of resources in the ambulance to maximize capabilities of EMTs; performance monitoring and evaluation.
Information Systems	Data were compiled with Excel and analyzed manually each month; access-based system now used with built-in macros for automatic analysis; station-level pretabulated data are sent to NAS Headquarters for evaluation.	Develop infrastructure for cloud-based, real-time data collection and reporting; GIS data collection and management to identify "hot spots" and population-based geospatial access gaps.
Evaluation	Time and efficiency indicators have been monitored since NAS inception; station locations, staffing requirements, and performance audits have been proposed using these data.	Add indicators for staff performance and patient outcome; telephone-based random assessment of quality of services provided from patients' perspectives.

Abbreviations: EMS, Emergency Medical Service; EMT, emergency medical technician; EMT-A, EMT Advanced; GIS, geographic information system; NAS, National Ambulance Service.

**APPENDIX 13 - POPULATION-LEVEL SPATIAL ACCESS TO
PREHOSPITAL CARE BY THE NATIONAL AMBULANCE
SERVICE IN GHANA**



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Population-level spatial access to prehospital care by the National Ambulance Service in Ghana

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Abstract

Background—Conditions requiring emergency treatment disproportionately affect low- and middle-income countries (LMICs), where there is often insufficient prehospital care capacity. To inform targeted prehospital care development in Ghana, we aimed to describe spatial access to formal prehospital care services and identify ambulance stations for capacity expansion.

Methods—Cost distance methods were used to evaluate areal and population-level access to prehospital care within 30 and 60 minutes of each of the 128 ambulance stations in Ghana. With network analysis methods, a two-step floating catchment area model was created to identify district-level variability in access. Districts without NAS stations within their catchment areas were identified as candidates for an additional NAS station. Additionally, five candidate stations for capacity expansion (e.g. addition of an ambulance) were then identified through iterative simulations that were designed to identify the stations that had the greatest influence on the access scores of the ten lowest access districts.

Results—Following NAS inception, the proportion of Ghana's landmass serviceable within 60 minutes of a station increased from 8.7 to 59.4% from 2004 to 2014, respectively. Over the same time period, the proportion of the population with access to the NAS within 60-minutes increased from 48% to 79%. The two-step floating catchment area model identified considerable variation in district-level access scores, which ranged from 0.05 to 2.43 ambulances per 100,000 persons (median 0.45; interquartile range 0.23–0.63). Seven candidate districts for NAS station addition and five candidate NAS stations for capacity expansion were identified. The addition of one ambulance to each of the five candidate stations improved access scores in the ten lowest access districts by a total 0.22 ambulances per 100,000 persons.

Conclusions—The NAS in Ghana has expanded its population-level spatial access to the majority of the population; however, access inequality exists in both rural and urban areas that can be improved by increasing station capacity or adding additional stations. Geospatial methods to identify access inequities and inform service expansion might serve as a model for other LMICs attempting to understand and improve formal prehospital care services.

Introduction

Conditions requiring emergency treatment are a major contributor to the global disease burden (1). Although public health interventions in the form of well-planned and organized prehospital care services reduce the morbidity and mortality associated with these conditions, such services are largely limited to high-income countries where only a fraction of deaths occur [2–5]. Among the reasons for this disparity is lack of access to prehospital

care and low-quality emergency medical services in many low- and middle-income countries (LMICs). Consequently, a significant proportion of preventable deaths occur in the prehospital setting in LMICs (6).

In response to global inequalities in emergency care, the World Health Assembly (WHA) passed Resolution 60.22 in 2007 (7). This document supported the effectiveness of improving emergency care services, including the need to “assess comprehensively the prehospital and emergency-care context including, where necessary, identifying unmet need” (7,8). Despite this, there remains a paucity of emergency care service evaluations in LMICs and none from Ghana.

The National Ambulance Service (NAS) in Ghana is one of the few formalized pre-hospital care systems in Africa. As such, it provides a unique opportunity to study spatial access to prehospital care services in an LMIC. Established in 2004 and expanded over the following decade, the NAS provides nationally coordinated around-the-clock prehospital care services nationally through 128 ambulance stations that respond to more than 20,000 calls annually (9). Although the NAS is a model prehospital care system in an LMIC, its utilization is relatively low and significant unmet prehospital care needs remain (10). For example, Ghana has an estimated 19 – 27 major injuries per 1,000 person years (11). Extrapolating to NAS service delivery, formal prehospital care is provided to fewer than 5% of these injuries, ignoring all other emergencies (10). In a country where the majority of trauma deaths occur before reaching hospital care, improving prehospital care services may have a substantial impact on trauma-related mortality.

The geographic organization of the NAS relative to the population, which has both access and equity implications for patients with emergency conditions, has not been evaluated. To address this gap, we aimed to quantify spatial access to NAS services nationally within a geographic information system (GIS). Using related methods, we also aimed to identify potential expansion locations to improve service equity. Quantifying population-level access to prehospital care is important for benchmarking and planning emergency infrastructure expansion for Ghana, as well as other LMICs more generally.

Methods

Setting

Ghana is a West African nation of 25.9 million people and a population density of 101.5 persons/km² (12). With a gross domestic product of US\$ 48.1 billion, Ghana is classified as a lower-middle income country by the World Bank (12). Although it is predominantly urbanized with several densely populated cities (e.g., Accra, Kumasi, Tamale), 47% of Ghana’s population lives in rural areas (12). Ghana has a road network of 101,000 km, 13% of which is paved (12). The major geographic features of Ghana are illustrated in Supplementary figure 1.

Study Data

NAS stations—A list of 128 ambulance station locations was provided by the NAS. Each station was geolocated using Google Earth (Google, Mountain View, CA). Data on the year

each station became operational and the number of ambulances per station were also provided by the NAS.

Population—National population data were represented by a 100 m² gridded population surface generated by the WorldPop project (13). This open-access initiative combines census data with ancillary datasets such as settlement locations and land use to model population distributions. As the majority of a census enumeration area's population resides within settlements, this method provides higher resolution approximations of the spatial distribution of populations than estimates based exclusively on the census-derived population counts of administrative areas (14,15). For Ghana, the dataset was built using the most recent census in 2010 and modeled estimates for 2015 based on United Nations population projections.

Road network—To create a suitable national road network, we combined data from Open Street Map (OSM) and the Centre for Remote Sensing and Geographic Information Services (CERSGIS). Primary roads (i.e., trunk roads connecting major cities) and secondary roads (i.e., inter-regional routes) were obtained from OSM, a crowd sourced mapping service that generates digitized, open-access maps through the use of aerial imagery, Global Positioning System (GPS) technology, and field maps (16). Tertiary roads (i.e., minor roads, tracks) were obtained from CERSGIS, a public centre commissioned by the Environmental Protection Agency that conducted a national survey of all engineered and non-engineered roads and digitized them using GPS technology (17). Two data sources were required as neither one on their own had the topology or resolution required for routing analyses.

Using ArcMap 10.3 (Esri, Redlands, CA), tertiary roads were extracted from the CERSGIS dataset and integrated with the OSM dataset with a 200-meter tolerance. Following topological verification, speed limits were assigned to each road class based on national traffic laws: 100 kmh⁻¹, 50 kmh⁻¹ and 30 kmh⁻¹ for primary, secondary and tertiary roads, respectively (18,19).

Data Analysis

Cost distance analysis—A cost distance analysis was performed to determine spatial access to NAS services. We superimposed a grid (i.e. cost surface) over the country; each cell was assigned an impedance value corresponding to the time required to traverse that cell. The technique identified the least time consuming path from any point on the grid to the nearest NAS service station. The cost surface was constructed using the national road network and each road's corresponding speed limit. Background cells were assigned a value corresponding to a speed of travel of 5 kmh⁻¹ (i.e. the average speed of walking). As ambulances are expected to remain on roads, other barriers, such as hydrological features, were not incorporated into the cost surface.

The proportion of the population with access to NAS services was evaluated by overlaying the gridded population surface over the cost distance analyses and identifying the sum of the population within 30- and 60-minutes of an NAS station. In Ghana, NAS stations are typically located near hospitals, therefore the 30- and 60-minute catchment areas used in our analyses were chosen to approximate prehospital intervals of 60- and 120-minutes, respectively. Both of these intervals have been used to define accessible health systems in

the emergency and trauma system literature (20,21). The primary outcome of this analysis was the proportion of Ghana's population residing within 30- or 60-minutes of an NAS station.

Sensitivity analysis—To evaluate model stability, two additional network datasets were built; travel speed for each road segment was augmented by $\pm 20\%$. The analysis was repeated for each of these road networks to create a lower and an upper estimate of the population proportion within each catchment (i.e. uncertainty interval).

Two-step floating catchment areas—To more accurately capture the interactions between ambulance availability and the population distribution, a two-step floating catchment area method (2SFCA) was used. This method generated an access score for each of Ghana's districts through a two-step process:

1. The station-level ambulance to population ratio was calculated by dividing the number of ambulances at a station by the population living within the station's 60-minute catchment area.
2. The ambulance to population ratios for all stations located within a 60-minute catchment area of a district's geographic centroid were then summed to create an access score that corresponded to a district-level ambulance to population ratio.

The 60-minute catchment areas were constructed using network analysis. Network analysis is a vector-based GIS method that estimates travel times based on the accumulated travel costs associated with traversing road segments and their connecting nodes (19). The analysis generated overlapping line segments around every station and district centroid corresponding to all roads within 60-minutes of travel time from each origin. District and NAS station catchment areas were created through the generation of a 2,500-meter buffer around each location's network of road segments. A 2,500-meter buffer was chosen as it was the minimum search tolerance required to link all NAS stations and district centroids to the road network for the network analysis. Selecting this buffer size therefore ensured all points could potentially be incorporated into a service area.

If a district's centroid was within a NAS station's catchment area, the district's population was included in the first calculation for that station. Similarly, if a NAS station was located within a district's catchment area, the station's ambulance to population ratio was included in the second calculation for that district. The resulting values represented the NAS access scores for each district, defined as the number of ambulances/100,000 persons. Lower values represented lower spatial access. Districts with no NAS stations within their 60-minute catchment areas were identified as candidate districts for an additional NAS station and excluded from the expansion simulation.

Capacity expansions were modeled within ArcMap by recalculating the district access scores following the iterative addition of one ambulance to each NAS station. The five stations with the greatest influence on the ten lowest access districts were identified through

this simulation as candidate stations for additional ambulances. Associations between access scores and district populations were analyzed using linear regression.

Results

All 128 NAS stations were successfully geolocated. The distributions of the NAS stations and population were grossly similar and the road network utilized in all analyses provided adequate national coverage (Supplementary figure 1).

Areal and population-level spatial access

The growth of the NAS between 2004 and 2014 is shown in Figure 2. Since the inception of the NAS, the proportion of Ghana's landmass that is serviceable within 60-minutes of an NAS station has increased from 8.7 to 59.4%.

Similarly, population-level access to NAS services within 60-minutes increased over the same period. Specifically, the proportion of the population within a 60-minute catchment area of a NAS station has increased from 37% in 2004 (uncertainty Interval [UI] 33.2–40.5%) to 79% in 2014 (UI 74.8–80.4%). The population within a 30-minute catchment area of a NAS station also increased over the 10-year period: 26% (UI 24.2–27.6%) to 61% (UI 55.3–66.0%) in 2004 and 2014, respectively (Table 1).

Identifying targets for station addition and expansion

The demographic and geographic properties of Ghana's districts are described in Table 2. Using the 2SFCA method, access scores were calculated for each district. These values were plotted by quintile with the corresponding population quintiles of each district (Figure 3). The catchment areas of seven districts, representing 3.9% of the country's population, did not contain any NAS stations (e.g. Sekyere East, Sene, Tain) (Table 3). These districts would potentially benefit from the addition of a NAS station.

There was a negative correlation between a district's population and access to NAS services: the more populated areas, particularly those in the southern half of the country, had correspondingly lower population-level spatial access to NAS services ($\beta -0.17$; $p=0.046$; $R^2=0.03$). Further, the level of access in each district was variable. District access scores among serviced districts ranged from 0.05 ambulances per 100,000 persons in the Obuasi Municipal District to 2.4 ambulances per 100,000 persons in the Sissala West District (median 0.45, interquartile range 0.23–0.63).

In addition to identifying districts without NAS stations within their 60-minute catchment areas, sequential infrastructure expansion simulations determined which stations had the greatest influence on the access scores of the ten lowest access districts. The five stations with the greatest impact are plotted in Figure 3. The addition of one ambulance to each of these five stations improved the access scores of the lowest access districts by a total of 0.22 ambulances per 100,000 persons (Table 4).

Discussion

This study aimed to describe spatial access to NAS services as a benchmark of prehospital care capacity and to inform emergency infrastructure expansion priorities for Ghana. Further, the study might be useful for other LMICs working to improve pre-hospital care coverage. From 2004 to 2014, the percent of the population with spatial access to NAS services within 30- and 60-minutes increased from 26 to 61% and 37 to 78%, respectively. However, significant disparities in spatial access exist; these areas would be useful targets for station creation and/or expansion to reduce unmet prehospital care needs.

GIS-based analyses are being used increasingly to improve healthcare organization (22). Although initially developed to describe spatial access to primary care, the 2SFCA and related models have subsequently been adapted to analyses of prehospital transport in high-income settings (23–25). The use of GIS-based methods for health service organization in LMICs has been more limited due, in part, to the limited availability of spatial data of sufficient quality (26).

Comparisons between the NAS and other prehospital care systems are challenged by a lack of published benchmarks from LMICs. In the United States, a response time target of 8-minutes for 90% of calls has been suggested, but this guideline is based largely on the results of one study of patients who suffered cardiac arrest (27,28). However, exceeding this standard for the other emergencies has not been shown to negatively impact outcome (27). A multicenter study by Newgard and colleagues did not demonstrate an association between prehospital interval and patient outcomes (29). However, the majority of the response time intervals in this study were less than 40 minutes, all participating sites provided professional prehospital care and care was provided within an integrated trauma system. Thus, the findings provide little generalizability to LMICs. South Africa, a middle-income nation with a more mature prehospital care system than Ghana, aims to respond to calls within 15 minutes in urban centers and 40 minutes in more rural areas (30,31). The findings from our analysis suggest that NAS expansion and resultant improvements in population-level spatial access to prehospital care is broadly compatible with this target. Nonetheless, 22% of the population remains outside of 60-minute NAS catchment areas (5.7 million individuals). Thus, significant opportunity to avert death and disability related to unmet prehospital care need exists. The documented NAS average prehospital time of 20-minutes suggests service utilization is predominantly occurring in more urban centers located proximally to NAS stations (10). Prior to NAS expansion, prehospital care services could be provided to populations currently without access by creating a tiered prehospital care system that incorporates trained laypeople to provide transport and basic care. This model has been effective in countries without formal prehospital care systems, including Iraq and Cambodia (32).

Despite the relatively high population-level spatial access to NAS services found in our analysis, there are notable variations in spatial access across Ghana. A significant proportion of the country and population remains unreachable within 1-hour given the current distribution of NAS stations (40.6% and 22%, respectively). While this results in inequalities for some rural populations, there are also considerable variations in access among urban

populations. The current single-ambulance capacity of most NAS stations in densely populated areas has resulted in poor access to formal prehospital care services relative to more sparsely populated serviceable areas. Detection of underserved areas is the major advantage of geospatial analyses, as they can inform the targeted creation and/or expansion of capacity to address these deficiencies and inequalities in access. Here, we demonstrate the adaptation of the 2SFCA technique to identify underserved districts and which stations, if expanded by the addition of a single ambulance, would have the greatest benefit for the most underserved populations. As this technique disregards district boundaries, it has the advantage of identifying stations that can simultaneously service multiple underserved districts. This results in more efficient improvements than simply adding stations to districts without them, or adding ambulances to stations in districts with low ambulance to population ratios. The districts and stations identified in our analysis provide guidance for the equitable expansion of NAS services in Ghana.

Although Ghana has relatively good population-level spatial access to prehospital care, NAS service utilization remains low. In 2014, the NAS performed 0.21 responses per ambulance per day, compared to the ambulance services of Shenzhen, China and New South Wales, Australia, which performed 6.0 and 46.7 responses per ambulance per day, respectively. Non-spatial barriers to access such as the knowledge, acceptability and affordability of NAS services and/or healthcare may affect utilization and are potential explanations for this disparity that require exploration (33). It is common to ignore non-spatial factors in analyses of prehospital emergency care by assuming the necessity of service overrides the knowledge, preferences and financial constraints of the patients (34). Such assumptions may be more reasonable in high-income settings with well-established prehospital care services. The results from this study suggest that these assumptions are invalid in Ghana. Thus, research regarding non-spatial barriers to prehospital care is required to identify factors contributing to the low utilization of NAS services that are amenable to intervention.

This study provides a robust analysis of population-level access to NAS services. However, certain limitations should be considered when interpreting the findings. First, this analysis did not incorporate the contributions of operational protocols, dispatch times, potential variations in traffic patterns, navigation errors and/or scene time. Although our results were stable with regards to changes in road travel speed, these additional factors might significantly impact revealed spatial access. This limitation underscores the need for georeferenced utilization data from prehospital care systems so that detailed comparisons between potential and revealed spatial access can be made. Second, the 2SFCA expansion simulation technique requires geographic centroids of districts being contained within NAS service areas before they can be included in the expansion simulation. In our analysis, seven districts were excluded due to the lack of proximity of their catchment areas to a NAS station. However, this represented only 3.9% of the population, maintaining the overall validity of the simulation to the vast majority of the population and provides important data for specific-district expansion. Third, we did not incorporate travel time from the scene to a capable facility. This is difficult to estimate given the critically low and variable emergency care capacity in Ghana, like other LMICs (35,36). Therefore, the access models we developed represent the time from response to prehospital care. Lastly, the models did not account for emergency condition rates nationally or by specific areas. Prehospital care need

may not be uniform across the country. Community-based studies of emergency condition incidence have not been systematically performed across Ghana to include in spatial access models. Despite these limitations, the results from this study demonstrate significant improvement in potential population-level spatial access of the NAS since its inception. Further, reasonable conclusions can be drawn regarding areas where spatial access could be improved with station capacity expansion.

Conclusion

The NAS in Ghana has expanded its spatial access to the majority of the population; however, more than 20% of the population remains unable to receive prehospital care within 60 minutes. Further, inequities in access persist in both rural and urban areas of the country and overall utilization rates remain low. To improve spatial access, several sites where station creation or expansion could provide the greatest benefit were suggested. Significant efforts to identify and redress non-spatial determinates of prehospital care access (e.g., knowledge, acceptability, affordability) are needed to improve NAS utilization. The use of GIS-based methods to identify access inequality, inform service expansion and suggest evaluation of other utilization barriers might serve as a model for other LMICs attempting to understand and improve formal prehospital care services.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

1. Mathers, C.; Fat, D.; Boerma, J. The Global Burden of Disease: 2004 Update. Geneva: World Health Organization; 2004.
2. Nathens AB, Brunet FP, Maier RV. Development of trauma systems and effect on outcomes after injury. *Lancet*. 2004 May 29; 363(9423):1794–1801. [PubMed: 15172780]
3. MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, et al. A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med*. 2006 Jan 26; 354(4):366–378. [PubMed: 16436768]
4. Dutton RP, Stansbury LG, Leone S, Kramer E, Hess JR, Scalea TM. Trauma mortality in mature trauma systems: are we doing better? An analysis of trauma mortality patterns, 1997–2008. *J Trauma*. 2010; 69:620–626. [PubMed: 20093983]
5. Norton R, Kobusingye O. Injuries. *N Engl J Med*. 2013 May 2; 368(18):1723–1730. [PubMed: 23635052]
6. Hofman K, Primack A, Keusch G, Hrynkow S. Addressing the Growing Burden of Trauma and Injury in Low- and Middle-Income Countries. *Am J Public Health*. 2005 Jan; 95(1):13–17. [PubMed: 15623852]
7. World Health Assembly. World Health Organization Website; 2007. Health systems : emergency-care systems [WHA Resolution 60.22]; p. 21-23.
8. World Health Assembly. Health Systems-Emergency Care Systems. 2007
9. Mock C. Strengthening care for the injured: success stories and lessons learned from around the world. 2010
10. Zakariah A, Stewart B, Boateng E, Achena C, Tansley G, Mock C. The birth and growth of the National Ambulance Service in Ghana: Instructive lessons for planning pre-hospital care in low- and middle-income countries. 2015

11. Mock CN, Abantanga F, Cummings P, Koepsell TD. Incidence and outcome of injury in Ghana: a community-based survey. *Bull World Health Organ.* 1999 Jan; 77(12):955–964. [PubMed: 10680242]
12. The World Bank. Ghana [Internet]. [cited 2015 Jun 30] Available from: <http://www.worldbank.org/en/country/ghana>.
13. The WorldPop Project. WorldPop Data [Internet]. [cited 2015 Jan 11] Available from: <http://www.worldpop.org.uk/>.
14. Linard C, Gilbert M, Snow RW, Noor AM, Tatem AJ. Population distribution, settlement patterns and accessibility across Africa in 2010. *PLoS One.* 2012; 7(2)
15. Tatem AJ, Noor AM, von Hagen C, Di Gregorio A, Hay SI. High resolution population maps for low income nations: combining land cover and census in East Africa. *PLoS One. Public Library of Science.* 2007 Jan 12.2(12):e1298.
16. OpenStreetMap [Internet]. [cited 2015 Jun 29] Available from: <http://www.openstreetmap.org/#map=6/-1.494/36.310>.
17. Mensa, M.; Sablah, E.; Amamoo-Otchere, E.; Mensah, F. Digital Mapping and GIS-Driven Feeder Road Network Database Management System for Road Project: Planning and Implementation Monitoring in the Feeder Road Sector. Accra, Ghana: 2006.
18. Damsere-Derry J, Afukaar FK, Donkor P, Mock C. Assessment of vehicle speeds on different categories of roadways in Ghana. *Int J Inj Contr Saf Promot.* 2008 Jun; 15(2):83–91. [PubMed: 18642165]
19. Derry JD, Afukaar FK, Donkor P, Mock C. Study of vehicle speeds on a major highway in Ghana: implication for monitoring and control. *Traffic Inj Prev.* 2007 Jun; 8(2):142–146. [PubMed: 17497517]
20. Hameed SM, Schuurman N, Razek T, Boone D, Van Heest R, Taulu T, et al. Access to trauma systems in Canada. *J Trauma.* 2010 Dec; 69(6):1350–1361. discussion 1361. [PubMed: 20838258]
21. Meara, JG.; Leather, AJM.; Hagander, L.; Alkire, BC.; Alonso, N.; Ameh, EA., et al. *Lancet Elsevier*; 2015 Apr 21. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development.
22. Cromley, EK.; McLaffery, S. GIS and Public Health. 2nd. New York, NY: The Guilford Press; 2012.
23. Lee, E. Systems. Vol. 2. Multidisciplinary Digital Publishing Institute; 2014 Mar 6. Designing Service Coverage and Measuring Accessibility and Serviceability of Rural and Small Urban Ambulance Systems; p. 34-53.
24. Wang F, Luo W. Assessing spatial and nonspatial factors for healthcare access: towards an integrated approach to defining health professional shortage areas. *Health Place.* 2005 Jun; 11(2): 131–146. [PubMed: 15629681]
25. Peters J, Hall GB. Assessment of ambulance response performance using a geographic information system. *Soc Sci Med.* 1999 Dec; 49(11):1551–1566. [PubMed: 10515636]
26. Gething PW, Amoako Johnson F, Frempong-Ainguah F, Nyakro P, Baschieri A, Aboagye P, et al. Geographical access to care at birth in Ghana: a barrier to safe motherhood. *BMC Public Health.* 2012; 12(1):1. [PubMed: 22214479]
27. Pons PT, Markovchick VJ. Eight minutes or less: Does the ambulance response time guideline impact trauma patient outcome? *J Emerg Med.* 2002; 23(1):43–48. [PubMed: 12217471]
28. Eisenberg MS, Bergner L, Hallstrom A. Cardiac resuscitation in the community. Importance of rapid provision and implications for program planning. *JAMA.* 1979; 241(18):1905–1907. [PubMed: 430772]
29. Newgard CD, Schmicker RH, Hedges JR, Trickett JP, Davis DP, Bulger EM, et al. Emergency medical services intervals and survival in trauma: assessment of the “golden hour” in a North American prospective cohort. *Ann Emerg Med.* 2010 Mar; 55(3):235.e4–246.e4. [PubMed: 19783323]
30. The World Bank. South Africa [Internet]. [cited 2015 Jul 4] Available from: <http://www.worldbank.org/en/country/southafrica>.
31. MacFarlane C, van Loggerenberg C, Kloock W. International EMS systems in South Africa--past, present, and future. *Resuscitation.* 2005 Feb; 64(2):145–148. [PubMed: 15680521]

32. Husum H, Gilbert M, Wisborg T, Van Heng Y, Murad M. Rural prehospital trauma systems improve trauma outcome in low-income countries: a prospective study from North Iraq and Cambodia. *J Trauma*. 2003 Jun; 54(6):1188–1196. [PubMed: 12813342]
33. McIntyre D, Thiede M, Birch S. Access as a policy-relevant concept in low- and middle-income countries. *Health Econ Policy Law*. 2009; 4(Pt 2):179–193. [PubMed: 19187569]
34. Schuurman N, Hameed SM, Fiedler R, Bell N, Simons RK. The spatial epidemiology of trauma : the potential of geographic information science to organize data and reveal patterns of injury and services. 2008; 51(5):389–395.
35. Stewart B, Quansah R, Gyedu A, Ankomah J, Donkor P, Mock C. Strategic assessment of trauma care capacity in Ghana. *World J Surg*. 2015
36. Ankomah J, Stewart B, Oppong-Nketia V, Koranteng A, Gyedu A, Quansah R, Donkor P, et al. Strategic assessment of the availability of pediatric trauma care equipment, technology and supplies in Ghana. *J Pediatr Surg*. 2015

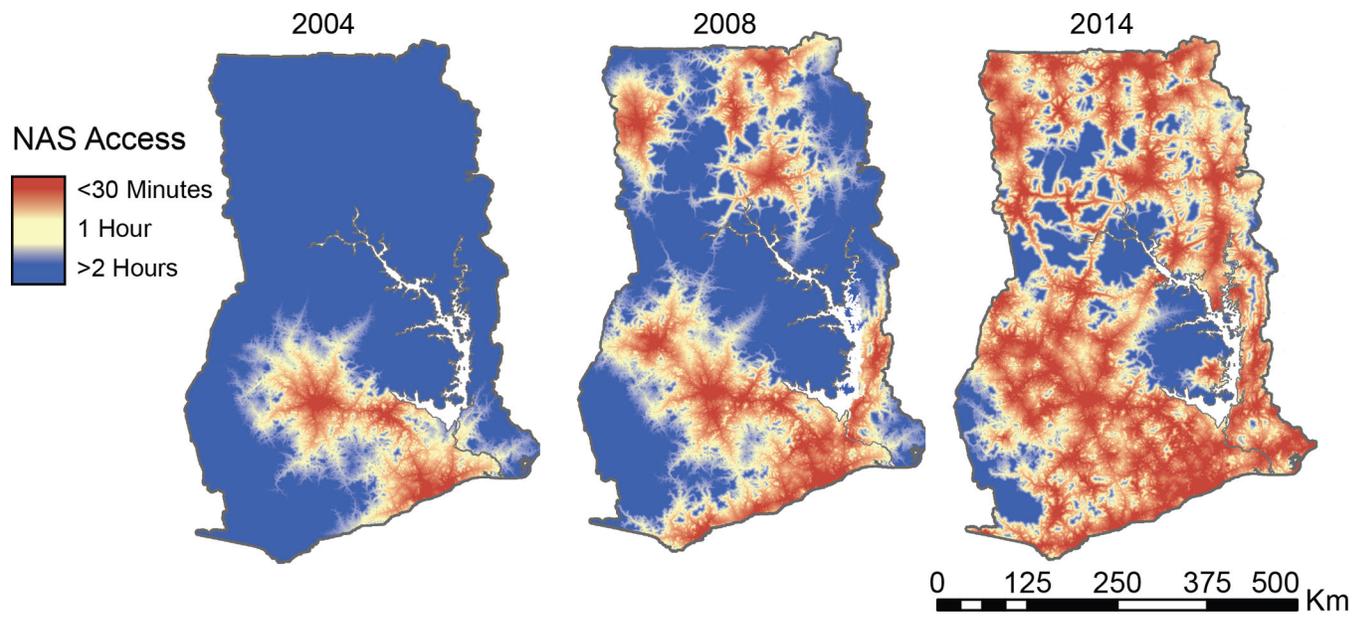


Figure 1. Areal coverage of the National Ambulance Service in Ghana between 2004 and 2014
Cost distance analysis illustrating improvements in areal coverage of the National Ambulance Service between 2004 and 2014.

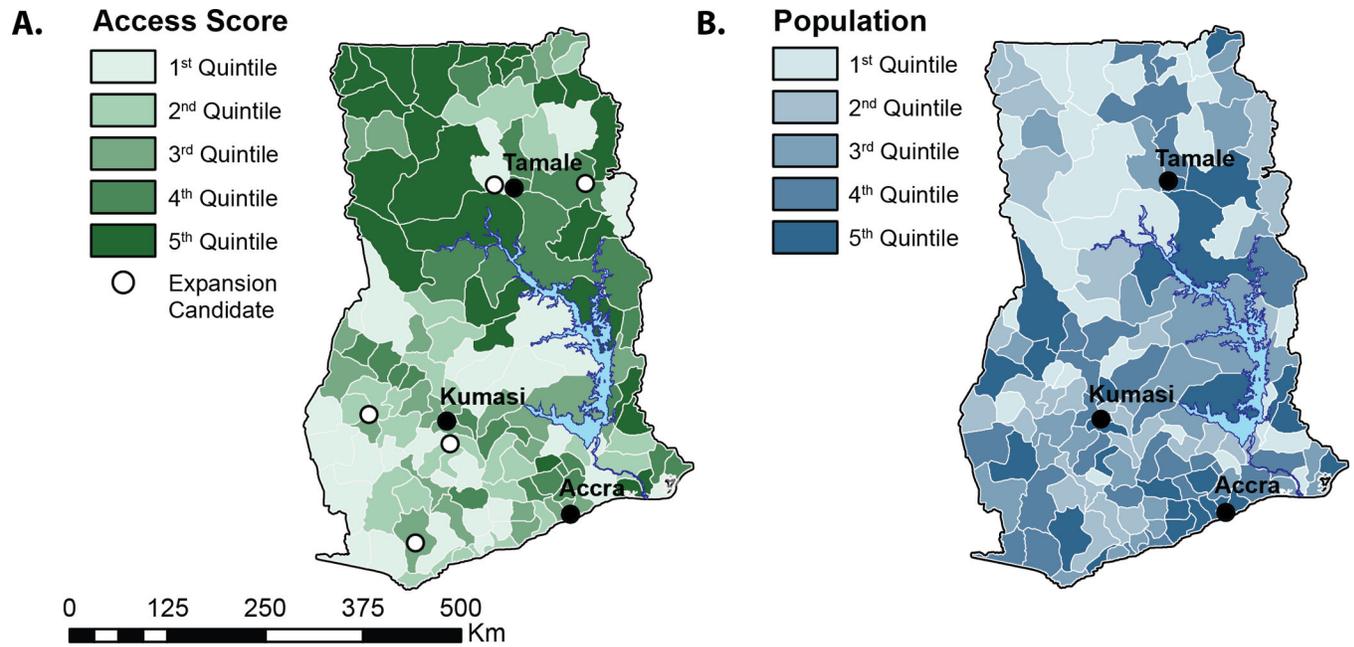


Figure 2. District-level National Ambulance Service access scores and populations by quintile
 A) Results of 2-step floating catchment area model demonstrating variations in spatial access. To create access scores, an ambulance/population ratio within a 60-minute service area of each National Ambulance Service (NAS) station was calculated. The ambulance/population ratios for all stations contained within each district's 60-minute catchment were then summed. The resulting values represented the access scores of the NAS for each district. Lower quintiles represent lower access. Expansion candidates represent the five ambulance stations that, when expanded by one ambulance, most significantly improved the ambulance/population ratio of the ten lowest access districts. B) District population quintiles to illustrate the relationship between population and spatial access to the NAS.

Table 1

Population-level spatial access to the National Ambulance Service in Ghana between 2004 and 2014.

Year	Population within 30-min area (%)	Uncertainty interval (%)	Population within 60-min area (%)	Uncertainty interval (%)
2004	26	24.2–27.6	48	33.2–40.5
2008	41	36.2–44.5	58	52.8–62.6
2014	61	55.3–66.0	79	74.8–80.4

Proportion of Ghana's population within 30- and 60-minute NAS catchment areas in 2004, 2008 and 2014. Uncertainty intervals represent the results of sensitivity analyses where road travel speeds were augmented by $\pm 20\%$. % - percent of national population; min – minutes.

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Table 2

Geographic and demographic characteristics of Ghana's districts

Feature	Median	Interquartile Range
Area (km ²)	1180.6	674.5–2199.8
Population	144,637	111,782–192,148
Number of NAS stations	1	0–1

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Table 3

Districts currently most underserved by the National Ambulance Service in Ghana identified as candidates for station creation.

District	Population (%)
Sekyere East	147,710 (0.54)
Sene	141,566 (0.52)
Tain	231,026 (0.85)
Asuogyaman	126,942 (0.47)
Aowin-Suaman	142,970 (0.52)
Bia	120,006 (0.44)
Nzema East	157,471 (0.58)
Total	1,067,693 (3.92)

Districts and their corresponding populations that had geographic centroids outside of any NAS service area. % - percent of national population.

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Table 4

National Ambulance Service stations with the greatest influence on the ten lowest access districts

Station City	Absolute increase in access scores (ambulances per 100,000 persons)
Yendi	0.07
Bekwai	0.05
Tarkwah	0.04
Tolon	0.03
Goaso	0.03
Total	0.22

Results of the two-step floating catchment area expansion simulation. Cities represent where their corresponding NAS station's expansion most significantly improves the ambulance/population ratios in the ten lowest access districts. Values represent the absolute increase in the access scores of the ten lowest access districts following expansion of the station by one ambulance.

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APPENDIX 14 - THE CORRELATION BETWEEN POVERTY
AND ACCESS TO ESSENTIAL SURGICAL CARE IN GHANA: A
GEOSPATIAL ANALYSIS



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The Correlation Between Poverty and Access to Essential Surgical Care in Ghana: A Geospatial Analysis

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Abstract

Background—Surgical disease burden falls disproportionately on individuals in low- and middle-income countries. These populations are also the least likely to have access to surgical care. Understanding the barriers to access in these populations is therefore necessary to meet the global surgical need.

Methods—Using geospatial methods, this study explores the district-level variation of two access barriers in Ghana: poverty and spatial access to care. National survey data were used to estimate the average total household expenditure (THE) in each district. Estimates of the spatial access to essential surgical care were generated from a cost-distance model based on a recent surgical capacity assessment. Correlations were analyzed using regression and displayed cartographically.

Results—Both THE and spatial access to surgical care were found to have statistically significant regional variation in Ghana ($p < 0.001$). An inverse relationship was identified between THE and spatial access to essential surgical care ($\beta -5.15$ USD, $p < 0.001$). Poverty and poor spatial access to surgical care were found to co-localize in the northwest of the country.

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Compliance with ethical standards

Conflict of interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

Conclusions—Multiple barriers to accessing surgical care can coexist within populations. A careful understanding of all access barriers is necessary to identify and target strategies to address unmet surgical need within a given population.

Introduction

Surgical conditions represent one of the leading contributors to the global burden of disease, accounting for up to a third of all disability-adjusted life years incurred annually [1]. The burden incurred from unmet surgical needs falls disproportionately on low- and middle-income countries (LMICs), whose populations are least able to access timely, affordable, and quality care [2, 3]. Before global surgical needs can be met, a thorough understanding of the barriers to accessing surgical care is required.

Access to care may be obstructed by a variety of factors including the availability, acceptability, or the affordability of a service [4]. The affordability of surgery is of particular concern in LMICs due to the cost of health care relative to average annual total household expenditures in many of these settings (THE). Impoverishment through healthcare seeking, known as catastrophic healthcare expenditure (CHE), is often defined by ten percent or more of annual THE being spent to access health care. Using this definition, one recent study suggested that over half of the world's population, including a significant proportion of Ghana's population, would be pushed into poverty should they require surgical care [1]. In addition to this high CHE, the acceptability and the availability of essential surgery have also been identified as access barriers for subsets of the Ghanaian population, suggesting that all of the major dimensions of access have relevance in Ghana [5, 6].

Although it is useful to consider the dimensions of service accessibility independently, it is perhaps more important to examine how they combine within a given population to develop targeted strategies to redress access inequalities. As the potential non-medical cost burden (i.e., travel costs, lodging, food, lost wages) associated with surgical care increases with travel time, poor availability of surgical care has the potential to increase the risk of CHE and rates of unmet surgical needs [7, 8]. Research from high-income countries has previously demonstrated that care is less accessible in more impoverished areas, suggesting these non-medical costs may be higher among the poor [9]. If this relationship was true for LMICs, recent estimates of CHE may underestimate the burden of non-medical costs for impoverished areas [2].

To clarify the relationship between poverty and access to essential surgical care in Ghana, we used geospatial methods to correlate a national poverty survey with a recent surgical capacity assessment. By identifying areas at elevated risk of CHE, it may be possible to target protective interventions at a more local level.

Methods

Study design

This study is an observational geospatial analysis of the relationship between annual THE and the spatial accessibility of essential surgical care in Ghana.

Study data

Data on annual THE in Ghana were obtained from the Ghana Living Standards Survey (GLSS), which is a nationally representative survey on consumption expenditure that was conducted between 2012 and 2013 on 18,000 households [10]. District administrative boundaries and population data were obtained from the Ghana Statistical Service and the WorldPop project, respectively [11, 12]. Data on national transportation networks were obtained from the Center for Remote Sensing and Geographic Information Services (CERSGIS) and OpenStreetMap, which are both providers of high-quality road network data in Ghana [13, 14]. The locations of hospitals capable of providing essential surgical services were obtained from a recent capacity assessment [5, 15, 16]. All geospatial analyses were conducted with ArcMap 10.1 (Esri, Redlands, CA). Statistical analyses were conducted using Stata v14.0 (StataCorp, College Station, TX).

Poverty mapping

Mean district THE was calculated by aggregating household-level THE estimates to the district corresponding to the household's primary sampling unit. Household weights were applied as an adjustment for the two-stage sampling design. The design of the GLSS does not permit the estimation of welfare measures at the district level; therefore, areal interpolation was performed using the Kriging method to obtain estimates of nominal THE in the nine districts that were not sampled [17].

Access estimates

Using previously described methods, cost-distance analyses were performed to model the average travel time to surgical care for each district [16]. Briefly, a grid (i.e., cost surface) was superimposed over the country; each cell was assigned an impedance value, which corresponded to the time required to traverse that cell. The cost surface was constructed using the national road network and each road's corresponding speed limit. Background cells were assigned a value corresponding to a speed of travel of 5 km h⁻¹ (i.e., the average speed of walking). The technique identified the least time-consuming path from any point on the grid to the nearest facility capable of providing essential surgical care [5, 18].

District-level mean travel times to essential surgical care were then calculated by averaging the values of the cells within each district. Averages were weighted by population distribution using a 100 m² grid-based population layer [12].

Correlations between a district's predicted THE and its average travel time to essential surgical care were analyzed using linear regression. Additionally, THE and travel time were divided into quantiles and displayed using a bivariate choropleth map to illustrate where these correlations were observed. Spatial autocorrelation of access and poverty were explored using the Global Moran's Index [19].

Results

The GLSS sampled 18,000 households and interviewed 16,772 persons (response rate = 93 %). Following areal interpolation, the median THE was 2257 USD annually [Interquartile

range (IQR) 1830–2753 USD]. Districts with lower annual THE, representing more impoverished areas, were concentrated in the northwest of the country. In contrast, districts with higher mean THE were concentrated in the southwest. Overall, THE was found to be strongly spatially dependent in Ghana (Moran Index 0.55, $p < 0.001$) implying that districts with similarly high or low THE tend to cluster together.

Following population-weighted aggregation of the cost-distance analysis to the district level, median travel time to a facility capable of providing essential surgical services was 61.7 min (IQR 35.6–96.8 min). The accessibility of essential surgical care exhibited a similar spatial pattern, with the northwest having worse access to surgical care than the south of the country. Nationally, essential surgical care access was found to be strongly spatially dependent (Moran Index 0.66, $p < 0.001$) suggesting that availability of essential surgical care is not evenly distributed over space but instead tends to cluster in a few areas.

An inverse relationship between mean travel time to essential surgical care and annual THE was identified and is illustrated in Fig. 1a. This association was confirmed by linear regression ($\beta -5.15$ USD, $p < 0.001$). A positive association was also found between THE and population density, suggesting poverty is concentrated in the more rural districts (Fig. 1b). A bivariate choropleth map illustrating the geographic distribution of poverty and access to surgical care is provided in Fig. 2. This map illustrates a concentration of impoverished districts with poor access to surgical care in the northwest of the country, representing districts that may be at particular risk of high rates of CHE.

Discussion

This study is an observational geospatial analysis of the regional variability of poverty and essential surgical accessibility in Ghana. Both annual THE and travel time to essential surgical care were found to be spatially dependent in this analysis. More notably, there was a significant inverse correlation between poverty and essential surgical accessibility in Ghana, suggesting impoverished areas have worse access to essential surgical care. The relationship between poverty and population density suggests the rural areas of Ghana are particularly at risk due to their lower mean THEs and their poorer access to centrally located healthcare resources. Poverty and low accessibility to essential surgical care were found to be highly co-localized in the predominantly rural northwestern region of the country, which represents a potential target for interventions designed to improve access to essential surgery.

Although no definition of CHE is universally accepted, one definition describes CHE as occurring when ten percent of the overall household expenditure is used to access health care [20]. Regardless of the specific definition used, the risk of CHE is thought to concentrate among the poor, particularly in healthcare systems predominately financed by out-of-pocket payments [21, 22]. Exacerbating the direct costs of accessing health care are the non-medical costs associated with food, travel, and lodging [22]. These costs are expected to increase with travel distance, making them particularly burdensome for patients accessing centralized services such as essential surgery [7]. By subsidizing travel costs or improving access to essential surgery in areas where poverty and poor access co-localize, it

may be possible to offset some of the financial burden of healthcare seeking and therefore have a positive impact on the rates of both CHE and unmet surgical needs.

The observation that the availability of medical care tends to vary inversely with the need for it in the population is not new. This observation, referred to as the inverse care law, was first formalized in 1971 and has subsequently been observed in several high-income settings [9, 23–25]. More recently, the inverse care law has even been described for primary care in sub-Saharan Africa [26]. To date, there has been little discussion of the inverse care law related to essential surgery in LMICs, which will be a vital consideration to achieving the United Nations Sustainable Development Goals [27]. In recent models of CHE, nonmedical costs are represented as a proportion of the medical costs, but these data suggest this could potentially underestimate the magnitude of impoverishment experienced by the poor who require surgical care [22]. Therefore, future models need to include sub-national estimates of non-medical costs to fully appreciate the impacts that these costs have on poverty and health-seeking behavior.

Although this study reports an important observation that can be used to strengthen surgical care access in Ghana and can serve as a useful model for other LMICs, several limitations need to be considered. First, the poverty data used were from a nationally representative population sample. Although the methods used to aggregate these data to the district level are well described and robust, they represent estimations with the possibility of error. Additionally, travel time estimates were also modeled. Estimating travel time is associated with unique challenges in LMICs due to the influence of variable road conditions and transportation infrastructure on overland speeds [28]. However, the methods used to model travel time in this study have previously been applied in LMICs and found to be better predict travel time than other methods [28, 29]. Finally, for the purposes of displaying CHE risk, this study assumes out-of-pocket payments and medical costs are homogeneous throughout Ghana. Although this is not strictly true, the variability in out-of-pocket payments is small and unlikely to influence the overall validity of the model [30]. Despite these limitations, these data provide strong evidence that poor access to essential surgery is concentrated among the poor in Ghana. Interventions designed to improve access to surgery should therefore be focused on these groups. Geospatial analyses are one approach that can be used to target these interventions in Ghana, and potentially other LMICs.

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References

1. Meara JG, Leather AJM, Hagander L, Alkire BC, Alonso N, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet*. 2015; doi: 10.1016/S0140-6736(15)60160-X
2. Meara JG, Leather AJM, Hagander L, Alkire BC, Alonso N, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet*. 2015; 386:569–624. DOI: 10.1016/S0140-6736(15)60160-X [PubMed: 25924834]

3. Stewart B, Quansah R, Gyedu A, Ankomah J, Donkor P, et al. Strategic assessment of trauma care capacity in Ghana. *World J Surg.* 2015; 39(10):2428–2440. DOI: 10.1007/s00268-015-3132-3 [PubMed: 26154575]
4. Penchansky R, Thomas JW. The concept of access: definition and relationship to consumer satisfaction. *Med Care.* 1981; 19:127–140. DOI: 10.2307/3764310 [PubMed: 7206846]
5. Stewart B, Tansley G, Gyedu A, Ofosu A, Donkor P, et al. Mapping access to essential surgical care in Ghana using the availability of Bellwether procedures. *JAMA Surg.* 2016; 151(8):e161239.doi: 10.1001/jamasurg.2016 [PubMed: 27331865]
6. Gyedu A, Abantanga F, Boakye G, Gupta S, Otupiri E, et al. Barriers to essential surgical care experienced by women in the two northernmost regions of Ghana: a cross-sectional survey. *BMC Womens Health.* 2016; 16:27.doi: 10.1186/s12905-016-0308-4 [PubMed: 27230890]
7. Kifle YA, Nigatu TH. Cost-effectiveness analysis of clinical specialist outreach as compared to referral system in Ethiopia: an economic evaluation. *Cost Eff Resour Alloc.* 2010; 8:13.doi: 10.1186/1478-7547-8-13 [PubMed: 20540766]
8. Groen RS, Samai M, Stewart KA, Cassidy LD, Kamara TB, et al. Untreated surgical conditions in Sierra Leone: a cluster randomised, cross-sectional, countrywide survey. *Lancet.* 2012; 380:1082–1087. DOI: 10.1016/S0140-6736(12)61081-2 [PubMed: 22898076]
9. Tudor Hart J. The inverse care law. *Lancet.* 1971; 297:405–412. DOI: 10.1016/S0140-6736(71)92410-X
10. Ghana Statistical Service (GSS). Ghana poverty mapping report. Accra; Ghana: 2015. p. 1-77.
11. Ghana Statistical Service. 2016. <http://www.statsghana.gov.gh/index.html>. Accessed 5 April 2016
12. The WorldPop Project. WorldPop Data. n.d.<http://www.worldpop.org.uk/>. Accessed 11 Jan 2015
13. Mensa, M., Sablah, E., Amamoo-Otchere, E., Mensah, F. Digital mapping and GIS-driven feeder road network database management system for road project: planning and implementation monitoring in the feeder road sector. Accra; Ghana: 2006.
14. OpenStreetMap. n.d.<http://www.openstreetmap.org/#map=6/-1.494/36.310>. Accessed 29 June 2015
15. Tansley G, Stewart B, Zakariah A, Boateng E, Achena C, et al. Population-level spatial access to prehospital care by the national ambulance service in Ghana. *Prehospital Emerg care.* 2016; doi: 10.3109/10903127.2016.1164775
16. Stewart BT, Gyedu A, Tansley G, Yeboah D, Amponsah-Manu F, et al. Orthopedic care capacity assessment and strategic planning in Ghana: mapping a way forward. *Ann Glob Health.* 2016; 82(3):560–561. DOI: 10.1016/j.aogh.2016.04.506
17. Goodchild MF, Lam NS-N. Areal interpolation: a variant of the traditional spatial problem. *Geo-processing.* 1980; 1:197–312.
18. Debas, HT, Donkor, P, Gawande, A, Jamison, DT, Kruk, ME., et al., editors. Disease control priorities, vol 1: Essential surgery. 3rd. World Bank; Washington, DC: 2015.
19. Moran P. Notes on continuous stochastic phenomena. *Biometrika.* 1950; 37:17–23. DOI: 10.2307/2332142 [PubMed: 15420245]
20. Xu K, Evans DB, Carrin G, Aguilar-Rivera AM, Musgrove P, et al. Protecting households from catastrophic health spending. *Health Aff.* 2007; 26:972–983. DOI: 10.1377/hlthaff.26.4.972
21. Meremikwu MM, Ehiri JE, Nkanga DG, Udoh EE, Ikpatt OF, et al. Socioeconomic constraints to effective management of Burkitt's lymphoma in south-eastern Nigeria. *Trop Med Int Health.* 2005; 10:92–98. DOI: 10.1111/j.1365-3156.2004.01348.x [PubMed: 15655018]
22. Shrimme MG, Dare AJ, Alkire BC, O'Neill K, Meara JG. Catastrophic expenditure to pay for surgery worldwide: a modelling study. *Lancet Glob Health.* 2015; 3(Suppl 2):S38–S44. DOI: 10.1016/S2214-109X(15)70085-9 [PubMed: 25926319]
23. Mercer SW, Watt GCM. The inverse care law: clinical primary care encounters in deprived and affluent areas of Scotland. *Ann Fam Med.* 2007; 5:503–510. DOI: 10.1370/afm.778 [PubMed: 18025487]
24. Pedersen A, Vedsted P. Understanding the inverse care law: a register and survey-based study of patient deprivation and burnout in general practice. *Int J Equity Health.* 2014; 13:121.doi: 10.1186/s12939-014-0121-3 [PubMed: 25495229]

25. Torjesen I. Analysis shows “postcode lottery” in access to GPs in England. *BMJ*. 2014; 348:g3688.doi: 10.1136/bmj.g3688 [PubMed: 24899639]
26. Moosa S, Wojczewski S, Hoffmann K, Poppe A, Nkomazana O, et al. The inverse primary care law in sub-Saharan Africa. *Br J Gen Pract*. 2014; doi: 10.3399/bjgp14X680089.e321
27. WHO (World Health Organization). *Health in 2015: from MDGs, Millennium Development Goals to SDGs, Sustainable Development Goals*. World Health Organization; Geneva: 2015.
28. Nesbitt RC, Gabrysch S, Laub A, Soremekun S, Manu A, et al. Methods to measure potential spatial access to delivery care in low- and middle-income countries: a case study in rural Ghana. *Int J Health Geogr*. 2014; 13:25.doi: 10.1186/1476-072X-13-25 [PubMed: 24964931]
29. Gething PW, Johnson FA, Frempong-Ainguah F, Nyarko P, Baschieri A, et al. Geographical access to care at birth in Ghana: a barrier to safe motherhood. *BMC Public Health*. 2012; 12:991.doi: 10.1186/1471-2458-12-991 [PubMed: 23158554]
30. Asante F, Chikwama C, Daniels A, Armar-Klemesu M. Evaluating the economic outcomes of the policy of fee exemption for maternal delivery care in Ghana. *Ghana Med J*. 2007; 41:110–117. DOI: 10.4314/gmj.v41i3.55277 [PubMed: 18470328]

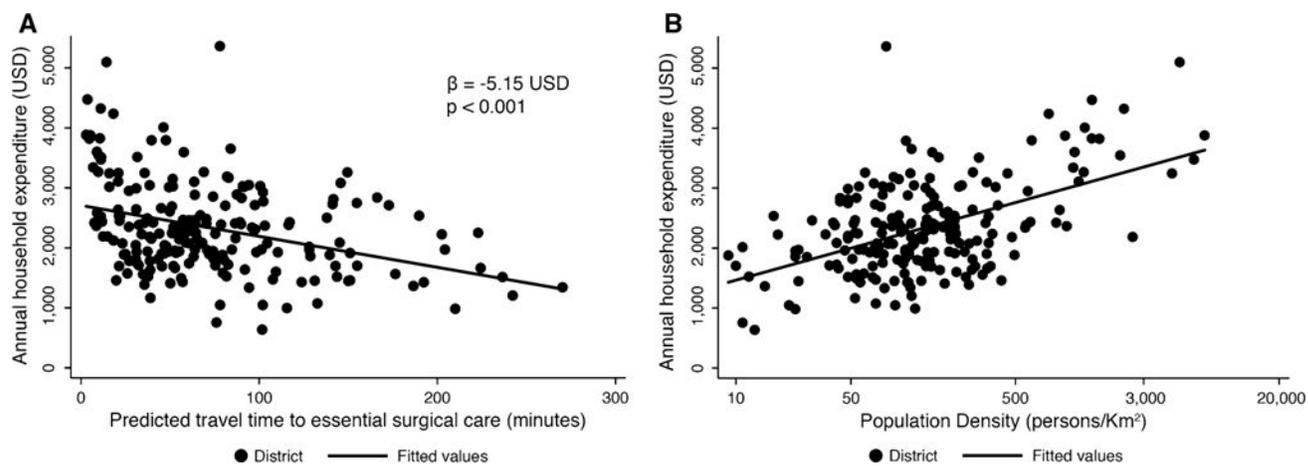


Fig. 1.
a Scatter plot with fitted line demonstrating an inverse relationship between total household expenditure and travel time to emergency surgical care. **b** Scatter plot with fitted line demonstrating a positive relationship between total household expenditure and population density. Note population density is expressed on a log scale

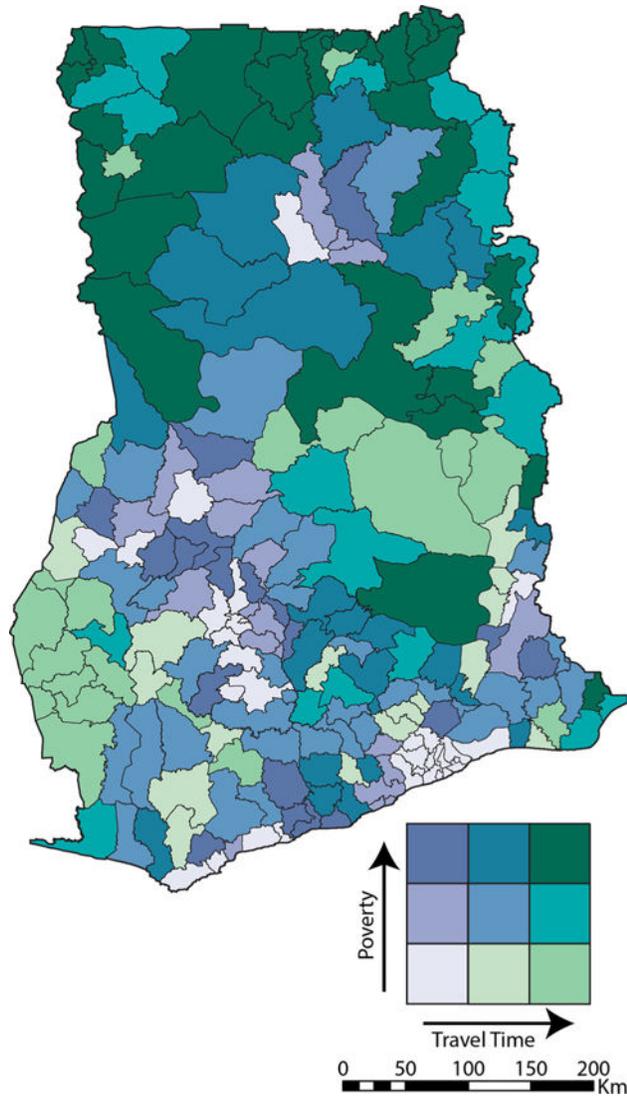


Fig. 2. Bivariate choropleth map demonstrating the colocalization of poverty and poor accessibility of surgical care in Ghana

APPENDIX 15 - TRIAGE CAPABILITIES OF MEDICAL
TRAINEES IN GHANA USING THE SOUTH AFRICAN TRIAGE
SCALE: AN OPPORTUNITY TO IMPROVE EMERGENCY CARE

Research

Triage capabilities of medical trainees in Ghana using the South African triage scale: an opportunity to improve emergency care



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Key words: Triage, Ghana, South African triage scale, diagnostic accuracy

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Abstract

Introduction: The incidence of emergency conditions is increasing worldwide, particularly in low- and middle-income countries (LMICs). However, triage and emergency care training has not been prioritized in LMICs. We aimed to assess the reliability and validity of the South African Triage Scale (SATS) when used by providers not specifically trained in SATS, as well as to compare triage capabilities between senior medical students and senior house officers to examine the effectiveness of our curriculum for house officer training with regards to triage. **Methods:** Sixty each of senior medical students and senior house officers who had not undergone specific triage or SATS training were asked to triage 25 previously validated emergency vignettes using the SATS. Estimates of reliability and validity were calculated. Additionally, over- and under-triage, as well as triage performance between the medical students and house officers was assessed against a reference standard. **Results:** Fifty-nine senior medical students (98% response rate) and 43 senior house officers (72% response rate) completed the survey (84% response rate overall). A total of 2,550 triage assignments were included in the analysis (59 medical student and 43 house officer triage assignments for 25 vignettes each; 1,475 and 1,075 triage assignments, respectively). Inter-rater reliability was moderate (quadratically weighted κ 0.59 and 0.60 for medical students and house officers, respectively). Triage using SATS performed by these groups had low sensitivity (medical students: 54%, 95% CI 49–59; house officers: 55%, 95% CI 48–60) and moderate specificity (medical students: 84%, 95% CI 82–89; house officers: 84%, 95% CI 82–97). Both groups under-triaged most 'emergency' level vignette patients (i.e. SATS Red; 80 and 82% for medical students and house officers, respectively). There was no difference between the groups for any metric. **Conclusion:** Although the SATS has proven utility in a number of different settings in LMICs, its success relies on its use by trained providers. Given the large and growing burden of emergency conditions, training current and future emergency care providers in triage is imperative.

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Introduction

The incidence of emergency conditions is increasing worldwide due to aging populations, urbanization and a lack of preventative care capacity [1-3]. This increasing burden falls disproportionately on low and middle-income countries (LMICs), which are ill equipped to provide emergency care [4, 5]. Opportunely, sound planning for and organization of emergency care can prevent deaths and reduce disability without the addition of significant costs [6-8]. An important part of emergency care organization is triage [9]. Triage improves emergency care service delivery by optimizing the utilization of existing and often scarce resources among patients depending on their acuity [10]. This process is particularly important in LMICs, which often have limited human and physical emergency resource capacity [11]. However, in many LMICs, triage is under-utilized, under-resourced, and poorly researched [12]. The South African Triage Scale (SATS) was developed in 2004 as a simple triage tool for South Africa [9]. The SATS has proven reliability and validity among providers who have undergone dedicated triage training, in emergency centers with limited resources both in and out of South Africa [12]. It has become widely used in LMICs, including first-level hospitals, which are typically the first point of care for patients with emergency conditions [12, 13]. Given these successes, the Ministry of Health (MoH) of Ghana recommended that the SATS become the triage method of choice for all hospitals in the country in 2011 [14, 15]. Although it is endorsed by MoH in Ghana and is expected to be in practice, triage training for current medical school trainees and existing non-emergency medicine providers has not been delivered. Although the SATS has proven construct validity and is effective in most LMIC settings, it has not been formally assessed among providers without dedicated SATS training. In Ghana, as in many first-level hospitals in LMICs, the healthcare provider caring for patients with emergency conditions is a general practitioner (GP) or a non-physician [4, 16]. Medical students graduate, spend two years as a house-officer to become a GP, and then are deployed to first-level hospitals countrywide for at least one year. These providers are often responsible for planning and organizing triage and emergency care at their facility [17, 18]. However, emergency care training of medical students and house officers has not been prioritized [19]; thus, many house officers who are becoming GPs and preparing for their national service in first-level hospitals may lack the knowledge necessary for effective triage. To address these gaps, we aimed to: i. assess the reliability and validity of the SATS when used by providers not specifically trained in SATS use; and ii. compare triage capabilities between senior medical students and senior house officers to examine the effectiveness of our house officer training curriculum with regards to triage. The findings might inform decisions around formal triage training for current and future medical trainees in Ghana, as well as LMICs more broadly.

Methods

Setting

Ghana is a heavily indebted, lower-middle income country in West Africa with a population of 26 million people and an annual per capita income of US\$ 1,760 [20]. This study focused on medical students and house officers at Komfo Anokye Teaching Hospital (KATH), which is a 1,200-bed tertiary facility that serves around 8.6 million Ghanaians [21]. After graduating medical school, students become house officers. House officers spend six months each in internal medicine, general surgery, obstetrics and gynecology, and

pediatrics. Additionally, house officers care for patients in the Accident and Emergency Unit (A&E) at KATH who have an emergency condition that falls under the auspices of each of the specialties. Some of the concepts surrounding triage are taught as part of a broader medical and surgical curriculum for both students and house officers (e.g. shock, injury management); however, neither curriculum includes modules specifically on triage theory or methods or SATS.

South African Triage Scale and its use in Ghana

The SATS is a physiologically based composite scoring system that includes the Triage Early Warning Score and a list of discriminators to triage patients into one of five color-coded acuity groups: Red – emergency (i.e. patient to be seen by a provider immediately); Orange – very urgent (i.e. patient to be seen by a provider within 10 minutes); Yellow – urgent (i.e. patient to be seen by a provider within 60 minutes); Green – routine (i.e. patient to be seen by a provider within 240 minutes); or Blue – dead. It was designed to be simple and used by nurses to alleviate the pressures of both human and physical resource limitations at hospitals in LMICs [12]. Given its simplicity and effectiveness in similar contexts, the MoH in Ghana designated SATS as the triage method of choice for casualty units across the country in 2011 [15]. It was incorporated into A&E care at KATH in 2010 [14]. At KATH, the nurses perform triage and patients are transported to and cared for in the respective color-coded ward. However, at the 187 first-level/district hospitals across the country, both nurses and GPs perform triage; the latter are responsible for organizing emergency care and deciding the order in which patients are resuscitated, treated, and/or referred to a higher level of care..

Survey

We created an online survey with 25 questions via SurveyMonkey (SurveyMonkey, CA, USA) using triage vignettes validated in South Africa and Pakistan [12, 22]. Each question described a patient presentation in the form of a vignette. The type and spectrum of emergencies presented in the vignettes were similar to situations encountered in Ghana. The vignettes included information on gender, age, presenting complaint, mode of arrival to the casualty unit, and vital signs. Some vignettes also included information from investigations that are often performed at the time of triage (e.g. blood glucose, hemoglobin). Respondents were asked to assign an acuity level to each vignette that corresponded to the SATS acuity groups (e.g. emergency, very urgent, urgent, or routine); vignettes that described a patient that should have been triaged blue were not included. Each question required a response (i.e. the participant could not proceed without answering the question). To avoid testing transgressions, questions were timed and question order was randomized for each respondent. The survey was performed in English, which is the language used to teach in Ghana.

Strategy and sample

To evaluate the survey acceptability, estimate sample size and set question times, 10 medical students and 10 house officers piloted the survey. The median medical student score was 40% and the median house officer score was 70%. Sample size was estimated to be 80 participants (i.e. 40 medical students and 40 senior house officers) using these pilot scores and:

Sample =

$$(Z_{\alpha/2} + Z_b)^2 \times [p_1(1 - \mu_1) + p_2(1 - \mu_2)] / (p_1 - p_2)^2$$

Where $Z_{\alpha/2}$ is the critical value of the normal distribution at $\alpha/2$ (i.e. 1.96 for a confidence level of 95%), Z_{β} is the critical value of the normal distribution at β (i.e. 0.84 for a power of 80%), and μ_1 and μ_2 are the expected proportions of correct triage responses in medical students and house officers (i.e. 40 and 70%, respectively).

A list of current senior medical students and senior house officers was obtained. Sixty randomly selected potential participants were approached from each group via both email and WhatsApp (WhatsApp, CA, USA). A link to an introduction and informed consent page was included in the messages. After providing informed consent, the survey continued to an instructions page and then the emergency vignettes.

Reliability and validity

To assess the extent to which the triage scale yields the same assessment between different respondents rating the same patient, we measured inter-rater reliability. In accordance with the Guidelines for Reporting Reliability and Agreement Studies (GRRAS), inter-rater reliability was assessed using the unweighted, linearly weighted and quadratically weighted κ (QWK) statistic [23]. The QWK considers the degree of disagreement between responses. A weighted κ places maximum weight at the two opposite ends of the triage scale (e.g. emergency and routine); therefore, it is identical to the intra-class correlation coefficient (ICC) [10]. Thus, the ICC was not reported given its equivalence with the QWK statistic [24]. Standard errors and confidence intervals were calculated using jackknife simulation. To allow apposite comparison with other SATS assessments, point estimates for each measure of inter-rater reliability were graded using the Landis and Koch classification system as follows: 0.0 - 0.20 - slight agreement; 0.21 - 0.40 - fair agreement; 0.41 - 0.60 - moderate agreement; 0.61 - 0.80 - substantial agreement; and 0.81 - 1.00 - almost perfect agreement [25]. Ten randomly selected respondents in each of the two groups re-triaged 10 randomly selected vignettes after one week. The results of this re-assessment were used to estimate intra-rater reliability by calculating the percentage of exact agreement, as well as the percentage of agreement allowing for one level of discrepancy in the triage assignments. The triage assignment accuracy of both groups was assessed by calculating the sensitivity, specificity, and over- or under-triage relative to the triage assignment for each of the vignettes suggested by an expert triage panel. The characteristics of and methods used by the expert panel for determining the triage assignment for each of the vignettes have been previously published [22]. Briefly, a panel of 18 emergency medicine physicians and emergency nurses from both developing and developed countries independently reviewed the vignettes. Using the Delphi technique, the panel reached consensus on the 'true' acuity of the patient in each vignette. They assigned an acuity based on their expert opinion rather than through the direct application of SATS; however, the acuities assigned mirrored SATS colors (i.e. emergency, very urgent, urgent, and routine). By using this method, triage assignment for each vignette follows emergency care acumen, and not exclusively the application of SATS itself. Over- and under-triage were interpreted using an accepted range for average under-triage of not more than 5 - 10% and an associated average over-triage rate of 30 - 50%. These ranges are considered acceptable by the American College of Surgeons Committee on Trauma.[26] Data were analyzed using STATA v13.1 (StataCorp, TX, USA).

Ethics

Ethical approval was obtained from the Kwame Nkrumah University of Science and Technology Committee on Human Research and Publication Ethics.

Results

Sixty senior medical students and sixty senior house officers were approached to participate in the survey. Fifty-nine medical students (98% response rate) and 43 house officers (72% response rate) completed the survey (84% response rate overall).

Reliability

A total of 2,550 triage assignments were included in the analysis, which consisted of 59 senior medical student and 43 senior house officer triage assignments for 25 vignettes each (1,475 and 1,075 triage assignments, respectively). Inter-rater reliability was fair in both groups, as measured by unweighted κ (Table 1). When measured by linearly and quadratically weighted κ , agreement was moderate. The level of exact intra-rater agreement among respondents was substantial (74%, 95% CI 67 - 80). When allowing for a one level of discrepancy between triage assignments, the level of intra-rater agreement increased to almost perfect (97%, 95% CI 95 - 99).

Validity

Table 2 and Table 3 present the accuracy of senior medical student and senior house officer triage assignment compared with those assigned by the expert panel, respectively. Overall, the triage using SATS performed by these groups had low sensitivity (medical students: 54%, 95% CI 49 - 59; house officers: 55%, 95% CI 48 - 60) and moderate specificity (medical students: 84%, 95% CI 82 - 89; house officers: 84%, 95% CI 82 - 97). Sensitivity was lower for "emergency" and "routine" triage assignments in both groups; however, these assignments had the highest specificity. Both groups over-triaged vignette patients whose triage assignment was "routine" (medical students: 77%, 95% CI 75 - 79; house officers: 79%, 95% CI 76 - 82), and nearly half of vignette patients who were "urgent" (Table 2 and Table 3). As reference, over-triage rates should be less than 50% [26]. Alarmingly, both groups under-triaged most of the "emergency" vignette patients (80 and 82% for medical students and house officers, respectively). "Very urgent" vignette patients were under-triaged in around half of triage assignments (53 and 52% for medical students and house officers, respectively). The published and acceptable under-triage rates should be less than 10% [26].

Difference between medical student and house officer triage

There was no evidence to suggest a difference between senior medical students and senior house officers with regards to inter-rater reliability (Table 1), triage assignment accuracy, or over- or under-triage (Table 2 and Table 3).

Discussion

This study aimed to demonstrate the reliability and validity of the SATS among providers not specifically trained in triage or SATS use and to compare medical student and house officer triage capabilities. Among untrained users, SATS demonstrated fair to moderate inter-rater reliability, low sensitivity, and moderate to high specificity. Most importantly, both groups over- and under-triaged

vignette patients too frequently compared to accepted standards. Lastly, there was no difference between the capabilities of medical students and house officers to triage vignette patients correctly. These findings highlight two issues: i. while the SATS is effective in many settings, it requires some degree of specific training to be used effectively; and ii. the house officer training curriculum at our teaching facility with regards to triage is inadequate. The SATS has been used successfully in each hospital level (i.e. first-level, referral hospitals, tertiary hospitals) and numerous LMICs [12-14]. In reports from these settings, training was uniformly included as part of the SATS implementation process. For example, the SATS was successfully implemented at the Médecins Sans Frontières (MSF) hospital in Timergara, Pakistan in 2011 [12]. Like government hospitals in LMICs, this hospital also faced human and physical resource limitations. Nurses performed triage at this hospital. Prior to SATS implementation, each nurse participated in a 1-hour training about triage and SATS use specifically. After nurses had been using the SATS for at least a month, the scale was assessed in detail with methods similar to those presented here. Inter-rater reliability in that setting was moderate to substantial and intra-rater agreement was high (exact agreement 87%, 95% CI 67 – 100). Further, the sensitivity and specificity compared to the same expert panel triage assignments as we used here were significantly higher than that achieved by the medical students and house officers. In general, the nurses in Pakistan over- and under-triaged patients less often than our respondents. However, the nurses, medical students, and house officers most often under-triaged 'emergency' vignette patients. The differences discussed above demonstrate the importance of ensuring that staff are trained in triage theory and methods, as well as the tool they are expected to use. Despite having completed two years as a house officer and caring for patients with emergency conditions during the same period, house officers were not able to triage vignette patients more effectively than medical students. At our facility, there is no structured curriculum for triage or emergency care teaching for a house officer. House officers learn on-the-job, such as on rounds, in the clinic or operating theater, or in departmental meetings. Given that there was no difference in the triage capabilities between medical students and house officers, this approach appears to be inadequate for teaching triage fundamentals. Other LMICs have built house officer training programs that include structured modules that cover a number of topics essential to providing care in LMIC as a GP in a first-level hospital after graduation, such as triage [27]. Further, some house officer programs evaluate their trainees based upon their knowledge of the topics covered in the modules [28]; emergency care vignettes such as these might be used to assess training quality and progress over time [22, 29]. Given that other studies have reported similar triage inabilities of providers graduating to first-level hospitals in other LMICs, this is not a problem that is unique to our teaching facility [30, 31]. Thus, teaching facilities in LMICs globally should consider assessing their curricula regarding triage, particularly for providers who will soon be transferred to first-level hospitals, where they will be without senior provider supervision.

A systematic review of emergency care in 59 LMICs reported that only 17 of the countries had an emergency physician; 27 countries had non-emergency consultants providing emergency care; and 15 countries had non-physicians or medical students providing emergency care [32]. In Ghana, we have a unique opportunity to improve emergency care training by including trainees in the operations of two newly developed emergency medicine residency programs [19]. Structured emergency medicine training at these facilities is currently available to residents. At Komfo Anokye Teaching Hospital there is a two-week rotation for medical students as they rotate through surgery. However, with local and national support, this two-week "exposure" could be expanded in length and

in availability. It could also be easily adjusted to include house officers. Additionally, these facilities might also serve as resources for existing providers from surrounding hospitals who might be insufficiently trained in triage or emergency care (e.g. supporting continuing education experiences). Further, advanced trainees or emergency medicine faculty might serve as trainers for existing providers in first-level and referral hospitals; such models have been effective in Papua New Guinea [33, 34]. While this study clearly demonstrates the importance of triage training and highlights current training deficiencies in our house officer curriculum, there are several limitations that should be considered when interpreting the results. First, the use of online vignettes lack patient cues and other important contextual information that can be used to improve triage accuracy. However, the vignettes and survey methods we used have been well validated in LMIC settings [12, 35]. Additionally, a published report compared the use of vignettes to live emergency patients for assessing inter-rater reliability and demonstrated an acceptable level of agreement between the two methods [36]. Second, the vignettes were developed in South Africa, which is more developed and has slightly different emergency condition epidemiology than Ghana [22, 37]. However, the vignettes were screened for contextual relevance and deemed appropriate by pilot groups of medical students and house officers. Next, the response rate of house officers was not high (72%). However, the sample frame of house officers was randomly selected, and they are all exposed to the same curriculum, or lack thereof. Lastly, some of the experts in the panel that developed consensus on the triage assignments for the vignettes were from high-income countries. These individuals might have over-assigned acuity (i.e. over-triaged vignette patients), which might partially explain why our groups under-triaged vignette patients. However, the triage assignments have been evaluated in South Africa and at a first-level MSF hospital in Pakistan with markedly lower under-triaged rates. Despite these limitations, these findings allow reasonable conclusions to be made about the importance of specific triage training for those who are to follow the SATS, as well as potential deficiencies in house officer curricula in Ghana and potentially LMICs more broadly.

Conclusion

Although the SATS has proven utility in a number of different settings and LMICs, its success relies on its use by trained providers. Given the large and growing burden of emergency conditions, training current students and house officers in triage is imperative. A number of triage and emergency care training models exist in high-income countries, and several LMICs have formed accredited training programs. However, ways in which LMIC emergency medicine training programs can have broader benefits for future and current first-level hospital providers is yet to be seen. In the meantime, the basics of triage must be taught to medical students and house officers. Otherwise, the cadre of providers at first-level hospitals in LMICs will be unable to quickly prioritize the care of critically ill and injured patients they will certainly encounter; inadequate triage capabilities at this level may waste scarce resources and lead to avertable death and disability.

What is known about this topic

- Triage is particularly important in LMICs, which often have limited human and physical emergency resource capacity;
- The SATS has proven utility in a number of different settings in LMICs.

What this study adds

- The success of SATS relies on its use by trained providers;
- Given the growing burden of emergency conditions in LMICs, training current and future emergency care providers in triage is imperative.

Competing interests

The authors declare no competing interest.

Authors' contributions

AG, KA, MD and BTS designed the study. AG, KA, BTS collected data or supervised its collection. AG, BTS and EN analyzed the data. AG, MO, RO & BTS prepared the manuscript. All authors have read and agreed to the final version of this manuscript and have equally contributed to its content and to the management of the case.

Tables

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References

1. Stewart B, Khanduri P, McCord C, Ohene-Yeboah M, Uranus S, Vega Rivera F et al. Global disease burden of conditions requiring emergency surgery. *British Journal of Surgery*. 2014 Jan; 101(1): e9-22. **PubMed | Google Scholar**
2. Gyedu A, Abantanga F, Kyei I, Boakye G, Stewart BT. Changing Epidemiology of Intestinal Obstruction in Ghana: Signs of Increasing Surgical Capacity and an Aging Population. *Digestive surgery*. 2015; 32(5): 389-96. **PubMed | Google Scholar**
3. Stewart BT, Wong E, Gupta S, Bastola S, Shrestha S, Kushner AL et al. Surgical need in an ageing population: a cluster-based household survey in Nepal. *Lancet*. 2015 Apr 27; 385(Suppl 2): S5. **PubMed | Google Scholar**
4. Stewart BT, Quansah R, Gyedu A, Ankomah J, Donkor P, Mock C. Strategic Assessment of Trauma Care Capacity in Ghana. *World J Surg*. 2015 Oct; 39(10): 2428-40. **PubMed | Google Scholar**
5. Japiong KB, Asiamah G, Owusu-Dabo E, Donkor P, Stewart B, Ebel BE et al. Availability of resources for emergency care at a second-level hospital in Ghana: a mixed methods assessment. *African Journal of Emergency Medicine*. 2015. **Google Scholar**
6. Mock C, Julliard C, Brundage S, Goosen J, Joshipura M. Guidelines for trauma quality improvement programmes. Geneva: World Health Organization. 2009. **Google Scholar**
7. Son NT, Mock C. Improvements in trauma care capabilities in Vietnam through use of the WHO-IATSIC Guidelines for Essential Trauma Care. *International journal of injury control and safety promotion*. 2006 Jun; 13(2): 125-7. **PubMed | Google Scholar**
8. Stewart BT, Gyedu A, Quansah R, Addo WL, Afoko A, Agbenorku P et al. District-level hospital trauma care audit filters: Delphi technique for defining context-appropriate indicators for quality improvement initiative evaluation in developing countries. *Injury*. 2016 Jan; 47(1): 211-9. **PubMed | Google Scholar**
9. Gottschalk SB, Wood D, DeVries S, Wallis LA, Bruijns S, Cape Triage G. The Cape Triage Score: a new triage system South Africa. Proposal from the Cape Triage Group. *Emerg Med J*. 2006 Feb; 23(2): 149-53. **PubMed | Google Scholar**
10. Tamburlini G, Di Mario S, Maggi RS, Vilarim JN, Gove S. Evaluation of guidelines for emergency triage assessment and treatment in developing countries. *Archives of disease in childhood*. 1999 Dec; 81(6): 478-82. **PubMed | Google Scholar**
11. Gove S, Tamburlini G, Molyneux E, Whitesell P, Campbell H. Development and technical basis of simplified guidelines for emergency triage assessment and treatment in developing countries. WHO Integrated Management of Childhood Illness Referral Care Project. *Archives of disease in childhood*. 1999 Dec; 81(6): 473-7. **PubMed | Google Scholar**
12. Dalwai MK, Twomey M, Maikere J, Said S, Wakeel M, Jemmy JP et al. Reliability and accuracy of the South African Triage Scale when used by nurses in the emergency department of Timergara Hospital, Pakistan. *S Afr Med J*. 2014 Mar 26; 104(5): 372-5 **PubMed | Google Scholar**
13. Rosedale K, Smith Z, Davies H, Wood D. The effectiveness of the South African Triage Score (SATS) in a rural emergency department. *South African Medical Journal*. 2011; 101(8): 537-40. **PubMed | Google Scholar**
14. Rominski S, Bell SA, Oduro G, Ampong P, Oteng R, Donkor P. The implementation of the South African Triage Score (SATS) in an urban teaching hospital, Ghana. *African Journal of Emergency Medicine*. 2014; 4(2): 71-5. **PubMed | Google Scholar**
15. Amoah AGB, Bannerman C, Zacharia A, Baah-Odoom D, Acquaye G, Addo WL et al. Policy and guidelines for hospital accident and emergency services in Ghana. Accra, Ghana: Ministry of Health, 2011. **Google Scholar**
16. Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT et al. Essential surgery: key messages from Disease Control Priorities, 3rd edition. *Lancet*. 2015 Feb 4. **Google Scholar**
17. Afari H, Hirschhorn LR, Michaelis A, Barker P, Sodzi-Tettey S. Quality improvement in emergency obstetric referrals: qualitative study of provider perspectives in Assin North district, Ghana. *BMJ open*. 2014; 4(5): e005052. **PubMed | Google Scholar**

18. Agyepong IA. Reforming health service delivery at district level in Ghana: the perspective of a district medical officer. *Health Policy Plan.* 1999 Mar; 14(1): 59-69. **PubMed | Google Scholar**
19. Martel J, Oteng R, Mould-Millman NK, Bell SA, Zakariah A, Oduro G et al. The development of sustainable emergency care in Ghana: physician, nursing and prehospital care training initiatives. *Journal of Emergency Medicine.* 2014 Oct; 47(4): 462-8. **PubMed | Google Scholar**
20. CIA World Factbook Washington, D.C.: United States Central Intelligence Agency; 2014 [cited 2015 April 12th]. Available from: <http://www.cia-worldfactbook.us/africa/ghana.html>. **Google Scholar**
21. Gyedu A, Baah EG, Boakye G, Ohene-Yeboah M, Otopiri E, Stewart BT. Quality of referrals for elective surgery at a tertiary care hospital in a developing country: An opportunity for improving timely access to and cost-effectiveness of surgical care. *Int J Surg.* 2015 Mar; 15: 74-8. **PubMed | Google Scholar**
22. Twomey M, Wallis LA, Myers JE. Evaluating the construct of triage acuity against a set of reference vignettes developed via modified Delphi method. *Emerg Med J.* 2013 Apr 24. **PubMed | Google Scholar**
23. Kottner J, Audige L, Brorson S, Donner A, Gajewski BJ, Hrobjartsson A et al. Guidelines for Reporting Reliability and Agreement Studies (GRRAS) were proposed. *J Clin Epidemiol.* 2011 Jan; 64(1): 96-106. **PubMed | Google Scholar**
24. Brenner H, Kliebsch U. Dependence of weighted kappa coefficients on the number of categories. *Epidemiology.* 1996 Mar; 7(2): 199-202. **PubMed | Google Scholar**
25. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics.* 1977 Mar; 33(1): 159-74. **PubMed | Google Scholar**
26. Mohan D, Rosengart MR, Farris C, Cohen E, Angus DC, Barnato AE. Assessing the feasibility of the American College of Surgeons' benchmarks for the triage of trauma patients. *Archives of surgery.* 2011 Jul; 146(7): 786-92. **PubMed | Google Scholar**
27. Cameron BH, Rambaran M, Sharma DP, Taylor RH. International surgery: the development of postgraduate surgical training in Guyana. *Can J Surg.* 2010 Feb; 53(1): 11-6. **PubMed | Google Scholar**
28. Wen LS, Geduld HI, Nagurney JT, Wallis LA. Africa's first emergency medicine training program at the University of Cape Town/Stellenbosch University: history, progress, and lessons learned. *Acad Emerg Med.* 2011 Aug; 18(8): 868-71. **PubMed | Google Scholar**
29. Carr SJ. Assessing clinical competency in medical senior house officers: how and why should we do it? *Postgrad Med J.* 2004 Feb; 80(940): 63-6. **PubMed | Google Scholar**
30. Muthaura PN, Khamis T, Ahmed M, Hussain SR. Perceptions of the preparedness of medical graduates for internship responsibilities in district hospitals in Kenya: a qualitative study. *BMC Med Educ.* 2015; 15(1): 178. **PubMed | Google Scholar**
31. Hexom B, Calvillo EJB, Babcock CA, Fowler R, Theodosios C, Sirleaf JA et al. A model for emergency medicine education in post-conflict Liberia. *African Journal of Emergency Medicine.* 2012; 2(1): 143-50. **PubMed | Google Scholar**
32. Obermeyer Z, Abujaber S, Makar M, Stoll S, Kayden SR, Wallis LA et al. Emergency care in 59 low- and middle-income countries: a systematic review. *Bulletin of the World Health Organization.* 2015 Aug 1; 93(8): 577-86G. **PubMed | Google Scholar**
33. Curry C. A perspective on developing emergency medicine as a specialty. *Int J Emerg Med.* 2008 Sep; 1(3): 163-7. **PubMed | Google Scholar**
34. Symmons D, Curry C. Rural hospital generalist and emergency medicine training in Papua New Guinea. *Emerg Med Australas.* 2007 Apr; 19(2): 151-4. **PubMed | Google Scholar**
35. Stewart BT, Gyedu A, Quansah R, Addo WL, Afoko A, Agbenorku P et al. District-level hospital trauma care audit filters: Delphi technique for defining context-appropriate indicators for quality improvement initiative evaluation in developing countries. *Injury.* 2016 Jan; 47(1): 211-9. **PubMed | Google Scholar**
36. Worster A, Sardo A, Eva K, Fernandes CM, Upadhye S. Triage tool inter-rater reliability: a comparison of live versus paper case scenarios. *J Emerg Nurs.* 2007 Aug; 33(4): 319-23. **PubMed | Google Scholar**
37. Data Visualizations Seattle, WA: Institute of Health Metrics and Evaluation; 2013 [cited 2015 May 27]. Available from: <http://vizhub.healthdata.org/gbd-cause-patterns/>. **Google Scholar**

Table 1: Measures of inter- and intra-rater reliability of senior medical student and senior house officer triage assignments of emergency vignettes using the South African triage scale in Ghana

	Senior medical students			Senior house officers		
	Estimate	(95% CI)	Agreement*	Estimate	(95% CI)	Agreement*
κ statistic						
Unweighted	0.28	(0.20 -0.38)	Fair	0.29	(0.21 - 0.39)	Fair
Linearly weighted	0.45	(0.34 -0.58)	Moderate	0.45	(0.34 - 0.58)	Moderate
Quadratically weighted	0.60	(0.48 -0.75)	Moderate	0.59	(0.48 - 0.74)	Moderate
Intra-rater reliability						
Exact agreement; %	77	(69 - 85)	Substantial	74	(65 - 83)	Substantial
Agreement with one SATS level discrepancy; %	98	(95 - 100)	Almost perfect	98	(95 -100)	Almost perfect

*Agreement according to Landis and Koch criteria; CI – confidence interval; SATS – South African Triage Scale

Table 2: Senior medical student triage assignments of emergency vignettes using the South African triage scale compared to those of an expert panel [22]

Expert triage assignments	Vignettes; n	Triage assignments; n	Senior medical student triage assignments; % (N=1,475)				SATS performance versus expert panel; % (95% CI)							
			Emergency	Very urgent	Urgent	Routine	Sensitivity		Specificity		Over-triage		Under-triage	
Emergency	7	413	62*	42	12	2	44	(39 - 49)	89	(87 - 91)	-	-	80	(78 -82)
Very urgent	6	354	33	37*	22	3	42	(37 - 47)	76	(74 - 79)	20	(18 - 22)	53	(50 - 55)
Urgent	6	354	5	19	47*	18	57	(52 - 62)	79	(77 - 82)	47	(45 - 50)	23	(21 - 25)
Routine	6	354	0	2	19	77*	74	(69 - 78)	93	(90 - 93)	77	(75 - 79)	-	-
Mean							54	(49 - 59)	84	(82 - 89)	48	(46 - 50)	54	(51 - 56)

SATS – South African Triage Scale; CI – confidence interval; *Medical student triage assignment matches the expert panel's triage assignment

Table 3: Senior house officer triage assignments of emergency vignettes using the South African triage scale compared to those of an expert panel.

Expert triage assignments	Vignettes; n	Triage assignments; n	Senior house officer triage assignments; % (N=1,075)		SATS performance versus expert panel; % (95% CI)									
			Emergency	Very urgent	Urgent	Routine	Sensitivity		Specificity		Over-triage		Under-triage	
Emergency	7	301	65*	41	13	0	42	(36 - 47)	91	(89 - 93)	-	-	82	(80 - 84)
Very urgent	6	258	29	36*	21	7	45	(38 - 51)	75	(72 - 78)	18	(16 - 20)	52	(49 - 55)
Urgent	6	258	5	21	47*	11	61	(55 - 67)	78	(75 - 81)	48	(44 - 51)	21	(18 - 23)
Routine	6	258	0	2	19	82*	72	(66 - 77)	91	(89 - 93)	79	(76 - 82)	-	-
Mean							55	(48 - 60)	84	(82 - 87)	49	(45 - 51)	53	(51 - 56)

SATS – South African Triage Scale; CI – confidence interval; *House officer triage assignment matches the expert panel's triage assignment

APPENDIX 16 – ORIGINAL APPROVED THESIS PROPOSAL

TRAUMA CARE CAPACITY ASSESSMENT AND QUALITY IMPROVEMENT IN GHANA USING THE CAPABILITY APPROACH

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INTRODUCTION

Injury is a public health problem worldwide, accounting for 6 million deaths and 11% of all disability-adjusted life years incurred annually.[1] The burden falls disproportionately on low- and middle-income countries (LMICs), which harbor 90% of these deaths.[2] Despite incurring a larger burden than HIV, tuberculosis and malaria combined, preventing and treating injuries have not been global health priorities.[3, 4] Thus, trauma care has been under-financed and under-resourced in LMICs.[5] Consequently, there is a significant number of deaths and disabilities that could be averted by better resourcing, planning and organization of trauma care.[6, 7]

Surgical and trauma care needs assessments

Planning for trauma care improvements in LMICs requires a baseline assessment of the availability of essential resources.[5, 8] Trauma care needs assessments at both the hospital and national levels have taken the form of capacity assessments.[9, 10] The four most widely used capacity assessment tools specifically for LMIC healthcare systems are: i) World Health Organization (WHO) *Tool for Situational Analysis to Assess Emergency and Essential Surgical Care*; ii) WHO *Guidelines for Essential Trauma Care*; iii) *Surgeons Overseas Personnel, Infrastructure, Procedures, Equipment and Supplies Assessment (PIPES)*; and iv) Harvard Humanitarian Initiative surgical capacity assessment tool.[8, 11-13] Using these, nearly 30 surgical or trauma care capacity assessments in LMICs have been performed.[5] Assessments have uniformly documented a lack of essential trauma care items and services, particularly at district-level hospitals.[5, 8, 9, 11, 12, 14-21] However, these assessment tools only examine resource inputs and do not systematically explore the causes of item deficiencies, thus limiting their

utility.[12] Resultantly, there has not been assessment of trauma care process or outcomes and few context-specific, actionable recommendations have been developed.[12] However, a recent systematic examination of the causes of deficiencies has been undertaken.[12] Shah et al performed an assessment of trauma care technology availability in Gujarat State, India. A lack of numerous specific items, many of which were low-cost, due to stock-outs and equipment breakdowns was common. However, locally manufactured items were fairly well supplied. The authors advocated for better procurement and stock-management, optimizing training for use of existing resources, and strengthening service contracts and local repair capabilities. Similar deficiency cause analyses, useful for planning targeted health systems strengthening interventions, have not been performed.

Rapid measures of surgical and trauma care capacity

Capacity assessments are time-consuming, relatively expensive and resource intensive. Therefore, there have been several proposed metrics for assessing surgical or trauma care capacity more rapidly and without the need to perform a detailed capacity assessment. The proposed metrics are: i) cesarean section to all operations performed ratio; ii) emergency herniorrhaphy to all herniorrhaphies performed ratio; and iii) surgical care rate (number of operations performed in a theatre per 100,000 persons).[22-24] While these metrics have been modeled or piloted in small studies, they have not been rigorously validated or compared to one another.[24, 25] Given that these metrics are being used to plan capacity improvement programs and are currently on the World Health Assembly docket for ratification, a study that simultaneously assesses surgical and trauma care capacity and collects data required to validate these metrics is urgently needed.[26]

The capacity-quality gap

Adequate capacity alone is not sufficient; surgical and trauma care must be of high quality (i.e. safe and effective) in addition to available to maximally avert death and disability.[5, 27, 28] Therefore, groups have identified healthcare systems with limited capacity and implemented surgical and/or trauma quality improvement programs in hospitals and LMIC healthcare systems.[9, 18, 29, 30] These programs have assumed that by providing a bolus of physical resources and the skills required to use them, there would be proportional improvements in the volume and quality of care. While capacity re-assessment after these programs were implemented in Sierra Leone and Vietnam demonstrated input improvements, the effect of such programs on the processes and outcomes of care (i.e. quality) remain unknown.[5, 7, 8, 18]

Challenges in assessing quality

Part of the challenge of assessing the quality of surgical and trauma care has been a lack of process metrics tailored to the resource limited settings, namely at first- and second-level hospitals (i.e. where the majority of injured persons receive care). In high-income countries, such metrics are routinely collected in the form of trauma care audit filters.[31, 32] Audit filters are descriptions of actions that should be performed, timeframes within which certain tests or procedures provided, or outcomes that are expected in injured persons.[32] However, existing filters rely on high-income healthcare system resources (e.g. computed tomography scan, timely access to surgical care). Consequently, they are inappropriate LMIC hospitals, limiting the evaluation of processes of care and, thus, quality improvement programs.

For the aforementioned reasons, longitudinal attempts at defining capacity, identifying actionable targets for improving capacity and/or quality, developing and implementing capacity development or quality improvement

programs and monitoring and evaluating their effectiveness have not been reported.[5] As a result, trauma care remains under-resourced, of poor quality and without useful metrics for serial assessment. Without overcoming these important obstacles, substantial improvements cannot be expected.

THEORETICAL FRAMEWORK

Trauma care capacity assessments have been invaluable for providing baseline data from which quality improvement programs could be benchmarked and building an evidence base for advocacy efforts.[5] However, these assessments have relied on measures of resource, poorly characterized targets for intervention and neglected the capability to provide quality care.[5, 12] Further, the resource-based approach to evaluating capacity fails to consider improvements that arise from maximizing the utility of current resources (e.g. resource synergy, value innovation, local ingenuity) and optimization of care processes. An assessment and quality improvement program that considers these potentials would be a valuable addition to trauma care development efforts.

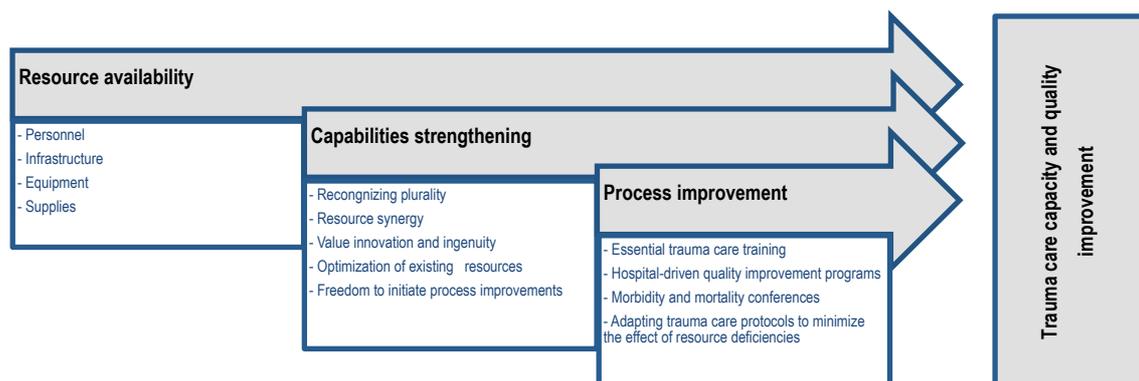
Opportunely, these potentials are the tenants of the 'capabilities' approach.[33] Amartya Sen, a Noble Prize winning development economist, described the capabilities approach in the 1980s.[34] Sen proposed that welfare is more related to an individual's ability to transform available resources into valuable activities, so-called functionings, than simply the availability of resources alone.[35] Prior to this, welfare was measured by the presence or absence of resources and their differential distribution between population groups.[36] While Sen does not reject the importance of equitable distribution of basic resources, he does suggest that welfare should instead be measured by what one is able to do with the available resources.[34] Although the capability approach was designed to measure a society's economic welfare via individual's capabilities, the approach appears readily adaptable to the healthcare environment where hospitals are the 'healthcare system' is the society, processes of care are the 'functionings,' and staff are its 'individuals.'

CONCEPTUAL FRAMEWORK

Improving the availability of personnel, infrastructure, equipment and supplies and the skills necessary to use them (i.e. capacity) at resource-limited hospitals improves trauma care.[8, 18] However, greater than expected improvements may occur with interventions rooted in the capability approach. These include interventions that empower hospital staff to develop local quality improvement programs (i.e. exercising freedom and option to improve circumstances with available resources) and determine ways in which individual hospitals can optimize existing resources (i.e. recognizing plurality, creating synergy, value innovation). Further, programs that identify potential or actual problems and respond by improving processes of care will better trauma care capacity and quality (Figure 1).

This shift in the paradigm of developing capability instead of capacity will require metrics that reflect the trauma care quality being provided at hospitals in tandem with available resources. By doing so, the effect of quality improvement programs can be adequately measured and useful recommendations defined.

Figure 1. Conceptual framework for hospital-based trauma care capacity improvement at the district-level.



PROBLEM STATEMENT

Capacity assessments and paradigms of healthcare development focus on what is deficient, not on what is available. Additionally, they neglect the 'functionings' of hospitals and staff required to turn available resources into quality care. Given that a rapid, dramatic increase in inputs is unlikely to occur for most LMICs, leveraging capabilities and optimizing and developing synergy with existing resources to improve the quality of trauma care is important and urgently needed. With this shift in paradigm, validation of currently used metrics and creation of new metrics that reflect the processes of trauma care at resource-limited hospitals will be required.

HYPOTHESIS

Ghana will have significant trauma care resource deficiencies at all hospital levels; however, existing resources can be leveraged to improve trauma care without new resource inputs using a quality improvement program rooted in the capabilities approach.

AIM

Assess the trauma care capacity in Ghana, develop and implement a trauma care quality improvement program centered on the capabilities approach, and evaluate its effectiveness with novel metrics (Figure 2).

OBJECTIVES

The study will be divided into three phases, each rooted in the capability approach (Figure 2): Capacity assessment – Objectives 1, 2, 3; Metric validation and creation: - Objectives 4, 5; Quality improvement program development – Objectives 6; and Quality improvement program implementation and evaluation – Objective 7. Together, the effect of using the capabilities approach to improve trauma care capacity in the absence of additional resources will be assessed.

Objective 1. Perform a nationwide trauma care capacity assessment of district-, regional- and tertiary-level hospitals to identify items and services that are deficient, as well as those that are available.

- Objective 2.* Perform a root cause analysis of the factors contributing to specific item deficiencies at each hospital to inform quality improvement interventions that aim to overcome item non-availability.
- Objective 3.* Compare the results from Objectives 1 and 2 with a trauma care capacity assessment done in Ghana in 2004 to identify factors contributing to improved availability, as well as to lower availability, so that these can further inform quality improvement interventions.
- Objective 4.* Compare the results of the capacity assessment at each hospital with results from surgical logbook data to examine the validity of currently proposed metrics for surgical capacity (e.g. cesarean section and emergency hernia ratios; surgical case rate per 100,000 population).
- Objective 5.* Use the Delphi technique¹ with Ghanaian district-level hospital experienced participants and expert traumatologists to develop consensus on 20 context-specific trauma care audit filters (i.e. data items that serve as proxies for quality trauma care and collective hospital capabilities) that will be used to monitor and evaluate quality improvement interventions.
- Objective 6.* Develop a context-specific, resource-appropriate course with modules designed to: i) teach established essential trauma care; ii) empower staffs to identify process-of-care problems and respond with homegrown quality improvement programs (i.e. freedom to execute functionings to improve care); iii) demonstrate the utility of morbidity and mortality conferences in improving trauma care; and iv) optimize the use of existing resources (i.e. recognize plurality, develop synergy, value innovate).
- Objective 7.* Implement the course at 6 purposively sampled district hospitals and evaluate it by determining the difference in the proportion of successfully performed audit filters per patient (derived from Objective 5) with a step-wedge design study.

METHODS

Objective 1 – capacity assessment

A total of forty of the 155 district, regional and tertiary hospitals will be purposively sampled to represent those most likely to care for injuries and the diversity of trauma care development, geography and local socioeconomics in Ghana. The World Health Organization's *Guidelines for Essential Trauma Care* resource matrix will be used as an assessment tool.[9, 37] Informed consent will be obtained by each of the Regional Health Directorates prior to assessment. Each of the following staff will be interviewed and asked to rate specific item availability: surgeons, anesthetists, medical officers, professionals, technicians and/or in-charges from the casualty, theatre, critical care, laboratory, radiology, physiotherapy, procurement, accounts and engineering departments. Item availability will be rated as: 0 – absent but should be present; 1 – inadequate, available to less than half of those who need it; 2 – partially adequate, available to more than half, but not to most who need it; or 3 – adequate, present and readily available to almost everyone in need and used when needed.[12, 18] Item availability ratings will be described using medians and ranges at each hospital level in keeping with previous assessments from other LMICs.[10]

Objective 2 – root cause analysis

For each of item rated 0 – 2 from the assessment above, factors contributing to non-availability will be systematically asked: 'The item has/is: never been present; present but broken and awaiting repairs; present and staff able to use it, but when they go home at night or on the weekend no one is available to fill the position; no

¹ The Delphi technique is a structured, systematic, iterative, data-driven method of obtaining consensus from a group of experts

staff member trained in using the available item; available, but lacks reagents or supplies; necessary equipment or supplies out of stock or insufficient in number; available, but only after pre-payment that prevents many from receiving the service or item; and/or other, with explanation.'[12] In addition, in-depth interviews with hospital administrators, accountants, stock managers and procurement officers (depending on the local context) will be performed to identify healthcare management, financing and supply chain problems. The data will be synthesized into root causes with content analysis and depicted by an Ishikawa diagram.

Objective 3 – comparison with the 2004 capacity assessment

In 2004, 10 hospitals were purposively sampled to represent district-level and regional hospitals in the southern regions (i.e. 7 of the 10 regions) of Ghana.[9, 10] To appositely compare hospitals from both studies, only the district-level and regional hospitals representing the southern regions from the assessment detailed by Objective 1 will be analyzed. Given the hospitals assessed in 2004 will be re-assessed in 2014 and the sampling frames will be the same in both studies, the Wilcoxon signed ranks test will be used to compare item availability ratings between the two assessments and within each hospital level. Lastly, factors contributing to improved availability, as well as equal or lower availability, at both small and large hospitals will be aggregated and graphically displayed with a box-plot to identify hurdles preventing improvements in item availability that remain to be confronted.

Objective 4 – validating metrics of surgical capacity

During each hospital visit outlined in Objective 1, another research team member will digitally record de-identified surgical logbook data. By doing so, the total number of cases, indications for surgery and procedures performed will be obtained. Subsequently, regression of hospitals' mean item availability rating (i.e. capacity) from Objective 1 with: i) cesarean section ratio; ii) emergency hernia ratio; and iii) surgical case rate per 100,000 population will be performed. This will allow examination of the validity of these three proposed metrics.

Objective 5 – developing district-level hospital trauma care audit filters

The capacity assessment and root cause analysis will be used to inform quality improvement interventions. Given monitoring and evaluation mechanisms must be in place prior to such interventions, resource-appropriate metrics that accurately reflect the process of providing trauma care and hospital capabilities must be developed (i.e. trauma care audit filters). Using the Delphi technique, twenty experts in district-level trauma care in Ghana will be selected to develop consensus on useful audit filters. An initial survey will be created that consisted of open-ended questions aimed to assess what participants consider important in a trauma care audit filter for the district hospital context, as well as what sort of data could be feasibly collected on a routine basis. In addition, a list of potential audit filters will be offered with an opportunity to respond to each in the form of a Likert scale from 0 to 10 (i.e. 0 – not useful filter; 10 - very useful filter). After the first round of responses, content analysis will be used for responses to open-ended questions to determine the qualities considered essential for trauma care audit filters by the participants. Proposed audit filters with a median Likert response of less than 8 will be further evaluated by open-ended questions in the second round to determine what features of the filters are not favorable. Similarly, questions with a median response greater than 9 will be returned with a question to identify what features are favorable. Audit filters with favorable ratings (i.e. median Likert response of at least 9) will be kept for the next round and new filters will be proposed using the themes identified from previous rounds, as well as those offered by the experts from Round I. This process will continue until there are 20 filters that the participants consider to be

feasibly collected at district hospitals and very useful proxies of quality trauma care and hospital capabilities (i.e. median Likert response of at least 9).

Objective 6 – essential trauma care and fundamentals of quality improvement programs course

To improve essential trauma care and cultivate the use of the capability approach in trauma care quality improvement, a training course will be created. The course will consist of four modules: i) context-specific and resource-appropriate district-level hospital essential trauma care principles adapted from the World Health Organization's *Guidelines for Essential Trauma Care*;[37] ii) problem-based learning case studies designed to empower staffs to identify process-of-care problems and develop local quality improvement programs; iii) mock morbidity and mortality conference to demonstrate its utility in improving trauma care quality; iv) round-table discussion with staff at individual hospitals regarding ways to optimize the use of existing equipment and supplies or overcome critical deficiencies. The course will target doctors and nurses, but will encourage any staff to participate (i.e. technicians, therapists, administrators).

Essential trauma care principles from well-established courses will be tailored to the district hospital resource-limitations identified by Objective 1. The first module will include didactics and practicals that cover topics including injury assessment, resuscitation, appropriate use of diagnostics, life-saving technical skills and referral practices. The second module will contain several potentially real cases that highlight principles of problem identification, process improvement and evaluation. The goal of this module is to engage hospital staffs to think about quality improvement at their facility and develop a sense of freedom/choice about improving their capabilities for trauma care. The third module will be a mock morbidity and mortality conference (M&M). M&M's are forums for openly discussing problems in patient care, near-miss events, medical or surgical errors, and patient deaths with the intent to improve faults in systems contributing to the event/error/death.[7, 31] The objective of this module will be to demonstrate the principles of M&M conference and provide a framework for hospital staff to run their own conference on a recurring basis and use the discussions to improve trauma care. The fourth module will be a round-table discussion about the particular resource challenges faced at the hospital. As a group, we will consider ways to adjust local trauma care protocols to maximize the use of the equipment and supplies available and overcome specific item non-availability. The course will not only teach or refresh essential trauma care principles and techniques, but also empower staff to improve trauma care at their facility and optimize the use of available equipment and supplies. By doing so, synergy with existing resources might be developed and quality of care might be improved without input of new resources.

Objective 7 – piloting and evaluating the training course

The course will be piloted and evaluated using a step-wedge design. Six district hospitals will be purposively selected to represent those that care for a high volume of trauma in Central and Eastern Region, Ghana (e.g. districts with high numbers of road traffic crashes reported by the Road Safety Commission, serving populous areas, responsible for a high number of non-walking injured referrals to regional hospitals reported by the Ghana Health Service). These regions are proposed based on poor current quality of trauma care, high trauma burden, well-functioning referral hospital and support of the Ghana Health Service representatives. Given the assumption that only one third of the anticipated audit filters are successfully performed for each patient (e.g. one large bore peripheral intra-venous catheter placed within 15 minutes of arrival), the goal of half of anticipated audit filters successfully performed for each patient, an alpha of 0.05 and a power of 0.8, at least 186 (i.e. 93 patients before

and 93 after) patients will need to be sampled. Since 5 to 15 non-walking injured patients present to busy district hospitals in Ghana each week, selecting 6 hospitals and collecting data for 6 months will give ample sample size for a well-powered evaluation of a difference in the proportion of successfully performed audit filters per patient before and after the course (at least 120 patients before and 120 after).

After consensus is reached on feasible and useful trauma care audit filters for district-level hospitals from Objective 5, our research team will meet with the Ghana Health Service and administrative and clinical staff at each of the 6 selected hospitals to determine an implementation plan for routine data collection. In the first month, weekly visits to the hospitals will take place with appraisals of the collected data to assess for completeness and accuracy. In addition, challenges and successes of data collection mechanisms will be discussed with the hospital staff so that problems can be overcome and instructive lessons for other hospitals can be learned. After the 1-month trial period, one hospital per month will undergo the training course detailed in Objective 6. The course will take 3-days to complete per hospital. The differences in the audit filters will be compared before and after the course to examine its effectiveness. In addition, immediately pre- and post-tests and a final questionnaire six months after the study is complete will be used to further examine the effectiveness of the course. The final questionnaire will re-test the essential trauma care principles, as well as document the number and types of quality improvement processes and presence of a formal M&M conference since the course.

ETHICAL CONSIDERATIONS

Ethical approval for each of the studies outlined above have been obtained from the Ghana Health Service (DGS/K5/052914; DGS/K5/031715), the Christian Health Association of Ghana (150029), the Kwame Nkrumah University of Science and Technology in Ghana (RC/279/14; AP/234/15; AP/127/15) and the University of Washington in the United States (46955; 49825) as appropriate.

Autonomy and respect for persons

Each hospital approached to participate in the aforementioned studies will have study process(es) explained in detail and be given the opportunity to ask questions and seek clarification. If they choose to participate, informed consent will be signed at the hospital administration level. In addition, informed consent will be performed for participants that take the pre- or post-tests associated with Objective 7. All data collected will be anonymous (i.e. without names, hospital number, detailed injury mechanism description, or location of injury or home). Therefore, results will not be presented in a manner that can identify patients, staff or hospitals.

Beneficence and non-maleficence

The data collection process will be specifically designed to not interfere with patient care or reflect poorly on individual hospitals or providers. Results of the capacity assessment, root cause analysis, 10-year comparison and metric validation studies will be useful for surgical and trauma care system planners in Ghana and in other LMICs. Though the collection of audit filters before the training course might not directly benefit the patients from whom the data are collected, future care required by that patient or by their community will likely benefit from the course and subsequent quality improvement programs that develop from it. The course is designed to reinforce established essential trauma care principles that are expected to be practiced at district-level hospitals. Therefore,

the risk to patients is minimal and far outweighed by the potential benefits of improving specific aspects of injury management and the planning and organization of trauma care at each hospital.

Justice and equity

The capacity assessment and root cause analysis will allow us to identify potential inequitable distribution of trauma care resources so that they can be remedied. The benefits of the program will occur at the hospital level; therefore, they will be available to all injured persons. In addition, the empowerment of hospital staff might lead to quality improvement programs that better care for other conditions (e.g. maternal hemorrhage, pediatric sepsis).

BUDGET

My salary, research budget and conference presentation travel are paid by the University of Washington Department of Surgery Research Reinvestment Fund and grants from the United States National Institutes of Health and Fogarty International Center (R25TW009345; D43-TW007267). The budget for the studies described by Objectives 1, 2, 3 and 4 have been previously submitted to the University of Washington and the monies dispersed. Objective 5 will be of no cost. The expected expenditures for Objective 6 and 7 are provided below.

Item	Unit cost	Units	Cost	Notes
Training team travel to each district (per person-trip)	\$15.00	144	2160	Average return bus fare for data collection training trips and trips for each course
Accommodation (per person-trip-night)	\$25.00	108	2700	Average guest-house fee per night for single room
Training and data collection supplies; printing (per audit filter or training course)	\$20.00	18	360	Handouts, medical consumables, etc. for audit filter collection implementation and training course
Per diems for training staff (per person-trip-day)	\$15.00	108	1620	Clinicians that will be taking time from potential work will assist with the course
Wireless USB dongles and credit for Open Data Kit course	\$40.00	6	240	Provides capacity for remote data upload
Epson EX5220 projector	\$505.00	1	505	For use during training courses
Total			\$7,585.00	

The budget assumes that 6 hospitals that will be visited by 4 person training-team: i) initially to build collaboration with district hospital staff; ii) a second time to implement trauma care audit filter data collection mechanism; iii) a third time for data collection quality assurance and troubleshooting; iv) a fourth time to give the training course; v) a fifth time for quality assurance and troubleshooting; and iv) a final sixth time for consolidating the program, feedback and an appreciation day. Between these major visits, individual team members will check-in with hospitals for troubleshooting and to give and receive feedback both in person and by telephone.

EXPECTED RESULTS

Objectives 1, 2 and 3 will demonstrate a lack of essential trauma care resources at all hospitals for a number of reasons that relate to a lack of training, item breakage, expensive user fees, weak supply chains, etc. The root cause analysis and comparison with the capacity assessment done 10 years ago will allow us to identify specific intervention targets.

Potentially, Objective 4 will demonstrate that capacity and the other proposed metrics are not highly predictive of one another. This will likely demonstrate that capacity does not necessarily result in greater output since the metrics neglect capabilities.

Objective 5 and 6 will be used for Objective 7. The training course will demonstrate improve post-test scores compared to pre-test and the final questionnaire will demonstrate that some hospitals have started local quality improvement initiatives and M&M conferences. Most importantly, there will be some improvement in the proportion of successfully completed audit filters per patient after the training course. Together, these findings would reflect improvements in capabilities.

EXPECTED OUTPUT

In addition to the peer-reviewed publications that will comprise the PhD dissertation, several important outputs are to be expected: stakeholder meetings with reports to the Ghana Health Service; peer-reviewed publications; and local and international presentations. Should the course materials be effective, the materials will be provided to each participating hospital and the Ghana Health Service for repeat use.

ORIGINALITY AND NEW KNOWLEDGE

Surgical and trauma care capacity assessments in LMICs are not new endeavors.[5] However, only one assessment has gone beyond simple inventory and further explored the causes for item non-availability, which was done for only a single state in India.[12] Therefore, the addition of the root cause analysis to this nationwide trauma care capacity assessment is a novel use of the technique and provides more useful results for identifying potential interventions to improve item availability and trauma care that has been previously performed. Additionally, no study has validated the use of the proposed capacity metrics with an actual capacity assessment. The results from this study will be useful for the global surgical community, which is trying to come to consensus on which metric(s) to ask countries to routinely report on.

Routine collection and analysis of trauma care audit filters is a compulsory part of being a registered trauma hospital in most high-income countries.[31] Given the lack of comprehensive trauma systems in LMICs, similar yet context-specific filters have not been developed. Consequently, the quality of trauma care at district-level hospitals is rarely evaluated. Therefore, the audit filters that are developed with formal Delphi technique will be novel, valuable and generalizable to other resource-limited district (i.e. first-level) hospitals attempting to evaluate trauma care.

Most trauma care training courses are designed for well-resourced settings (i.e. Advanced Trauma Life Support).[38] The course we propose includes teaching essential trauma care principles for district-level hospital staff and three unique modules, which will be specifically designed to improve trauma care through enhancing capabilities. Moreover, the model we propose for trauma care improvement is fundamentally different than those that have been performed previously. The focus of the proposed work is not on the deficiencies we find, but on the improvement of trauma care that can be achieved with ensuring essential trauma care knowledge and skill, empowering hospital staffs to exercise their option for developing quality improvement programs within their context, and optimizing the use of existing resources so that, potentially, synergy might occur and specific deficiencies might be overcome. Together, these constitute a paradigm shift from a resource-based capacity improvement model to one that emphasizes the capability approach.

References

1. Lozano, R., et al., *Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010*. *Lancet*, 2012. **380**(9859): p. 2095-128.
2. IHME. *Data Visualizations*. Global Burden of Disease Cause Patterns 2013 [cited 2014 12/7/2014]; Available from: <http://vizhub.healthdata.org/gbd-cause-patterns/>.
3. *Injuries and violence: the facts*. 2010, World Health Organization: Geneva.
4. Mock, C., *Confronting the global burden of surgical disease*. *World J Surg*, 2013. **37**(7): p. 1457-9.
5. Carlson, L.C., et al., *Moving from Data Collection to Application: A Systematic Literature Review of Surgical Capacity Assessments and their Applications*. *World J Surg*, 2015. **39**(4): p. 813-21.
6. Mock, C., et al., *Strengthening care for the injured: success stories and lessons learned from around the world*. 2010, World Health Organization: Geneva.
7. Mock, C., et al., *Guidelines for trauma quality improvement programmes*. 2009, World Health Organization: Geneva.
8. Groen, R.S., et al., *A tool and index to assess surgical capacity in low income countries: an initial implementation in Sierra Leone*. *World J Surg*, 2012. **36**(8): p. 1970-7.
9. Mock, C., et al., *Evaluation of Trauma Care capabilities in four countries using the WHO-IATSIC Guidelines for Essential Trauma Care*. *World J Surg*, 2006. **30**(6): p. 946-56.
10. Quansah, R., C. Mock, and F. Abantanga, *Status of trauma care in Ghana*. *Ghana Med J*, 2004. **38**(4): p. 149-152.
11. Linden, A.F., et al., *Challenges of surgery in developing countries: a survey of surgical and anesthesia capacity in Uganda's public hospitals*. *World J Surg*, 2012. **36**(5): p. 1056-65.
12. Shah, M.T., et al., *Assessment of the Availability of Technology for Trauma Care in India*. *World J Surg*, 2014. **39**(2): p. 363-72.
13. Chao, T.E., et al., *Survey of surgery and anesthesia infrastructure in Ethiopia*. *World J Surg*, 2012. **36**(11): p. 2545-53.
14. Choo, S., et al., *Assessment of capacity for surgery, obstetrics and anaesthesia in 17 Ghanaian hospitals using a WHO assessment tool*. *Trop Med Int Health*, 2010. **15**(9): p. 1109-15.
15. Gupta, S., et al., *Burn management capacity in low and middle-income countries: A systematic review of 458 hospitals across 14 countries*. *Int J Surg*, 2014.
16. Wong, E.G., et al., *The International Assessment of Capacity for Trauma (INTACT): an index for trauma capacity in low-income countries*. *J Surg Res*, 2014. **190**(2): p. 522-7.
17. Wong, E.G., et al., *Prioritizing injury care: a review of trauma capacity in low and middle-income countries*. *J Surg Res*, 2014.
18. Son, N.T. and C. Mock, *Improvements in trauma care capabilities in Vietnam through use of the WHO-IATSIC Guidelines for Essential Trauma Care*. *Int J Inj Contr Saf Promot*, 2006. **13**(2): p. 125-7.
19. Son, N.T., et al., *Assessment of the status of resources for essential trauma care in Hanoi and Khanh Hoa, Vietnam*. *Injury*, 2007. **38**(9): p. 1014-22.
20. LeBrun, D.G., et al., *Prioritizing essential surgery and safe anesthesia for the Post-2015 Development Agenda: operative capacities of 78 district hospitals in 7 low- and middle-income countries*. *Surgery*, 2014. **155**(3): p. 365-73.

21. Markin, A., et al., *A quantitative analysis of surgical capacity in Santa Cruz, Bolivia*. J Surg Res, 2013. **185**(1): p. 190-7.
22. Samuel, J.C., et al., *Development of a ratio of emergent to total hernia repairs as a surgical capacity metric*. Int J Surg, 2014. **12**(9): p. 906-11.
23. Hughes, C.D., et al., *Ratio of cesarean deliveries to total operations and surgeon nationality are potential proxies for surgical capacity in central Haiti*. World J Surg, 2013. **37**(7): p. 1526-9.
24. Weiser, T.G., et al., *An estimation of the global volume of surgery: a modelling strategy based on available data*. Lancet, 2008. **372**(9633): p. 139-44.
25. Stewart, B., et al., *An analysis of cesarean section and emergency hernia ratios as markers of surgical capacity in low-income countries affected by humanitarian emergencies from 2008 – 2014 at Médecins Sans Frontières Operations Centre Brussels projects*. PLoS Current Disasters, 2015.
26. *Strengthening emergency and essential surgical care and anaesthesia as a component of universal health coverage*, in EB136.R7, W.H. Assembly, Editor. 2015.
27. Grimes, C.E., et al., *Cost-effectiveness of surgery in low- and middle-income countries: a systematic review*. World J Surg, 2014. **38**(1): p. 252-63.
28. Stewart, B., et al., *Barriers to elective surgical care in low- and middle-income countries: a pilot study of a comprehensive assessment tool in Ghana*. Submitted to World Journal of Surgery, 2015.
29. Kingham, T.P., et al., *Quantifying surgical capacity in Sierra Leone: a guide for improving surgical care*. Arch Surg, 2009. **144**(2): p. 122-7; discussion 128.
30. Mendis, S., et al., *Gaps in capacity in primary care in low-resource settings for implementation of essential noncommunicable disease interventions*. Int J Hypertens, 2012. **2012**: p. 584041.
31. Stelfox, H.T., et al., *Quality indicators for evaluating trauma care: a scoping review*. Arch Surg, 2010. **145**(3): p. 286-95.
32. Evans, C., et al., *Audit filters for improving processes of care and clinical outcomes in trauma systems*. Cochrane Database Syst Rev, 2009(4): p. CD007590.
33. Sen, A., *Commodities and capabilities*. 1985, Amsterdam & New York: North-Holland.
34. MacMurrin, S., *The Tanner lectures on human values*. 2 ed. Equality of what?, ed. A. Sen. Vol. 4. 1980, Cambridge: Cambridge University Press.
35. Clark, D.A., *The Capability Approach: Its Development, Critiques and Recent Advances*. 2014, Global Poverty Research Group: Swindon, UK.
36. Sen, A., *Development as freedom*. 2001, New York: Oxford University Press.
37. Mock, C., et al., *Guidelines for essential trauma care*. 2004, World Health Organization: Geneva.
38. Mock, C.N., et al., *The development of continuing education for trauma care in an African nation*. Injury, 2005. **36**(6): p. 725-32.

APPENDIX 17 – AMENDMENT TO ORIGINAL APPROVED
THESIS PROPOSAL

Request for Amendment to PhD Proposal

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Amendment requested: removal of Objectives 6 and 7 in original proposal, and replacement with new Objective 6 - 8, as below.

Original Objectives

- Objective 1.* Perform a nationwide trauma care capacity assessment of district-, regional- and tertiary-level hospitals to identify items and services that are deficient, as well as those that are available.
- Objective 2.* Perform a root cause analysis of the factors contributing to specific item deficiencies at each hospital to inform quality improvement interventions that aim to overcome item non-availability.
- Objective 3.* Compare the results from Objectives 1 and 2 with a trauma care capacity assessment done in Ghana in 2004 to identify factors contributing to improved availability, as well as to lower availability, so that these can further inform quality improvement interventions.
- Objective 4.* Compare the results of the capacity assessment at each hospital with results from surgical logbook data to examine the validity of currently proposed metrics for surgical capacity (e.g. cesarean section and emergency hernia ratios; surgical case rate per 100,000 population).
- Objective 5.* Use the Delphi technique with Ghanaian district-level hospital experienced participants and expert traumatologists to develop consensus on 20 context-specific trauma care audit filters (i.e. data items that serve as proxies for quality trauma care and collective hospital capabilities) that will be used to monitor and evaluate quality improvement interventions.
- Objective 6.* Develop a context-specific, resource-appropriate course with modules designed to: i) teach established essential trauma care; ii) empower staffs to identify process-of-care problems and respond with homegrown quality improvement programs (i.e. freedom to execute functionings to improve care); iii) demonstrate the utility of morbidity and mortality conferences in improving trauma care; and iv) optimize the use of existing resources (i.e. recognize plurality, develop synergy, value innovate).
- Objective 7.* Implement the course at 6 purposively sampled district hospitals and evaluate it by determining the difference in the proportion of successfully performed audit filters per patient (derived from Objective 5) with a step-wedge design study.

New Objective

- Objective 6.* Create and pilot a tool to systematically assess barriers to essential surgical care.

Objective 7. Perform an assessment of population-level spatial access to essential surgical and trauma care.

Objective 8. Perform a system-level, consensus-based assessment using a novel tool that aims to identify gaps and generate action priorities for the following domains of the emergency, trauma, and surgical care system: system organization and governance, financing, data, quality improvement, scene care, transport and transfer, facility-based care, rehabilitation, and emergency and disaster preparedness.

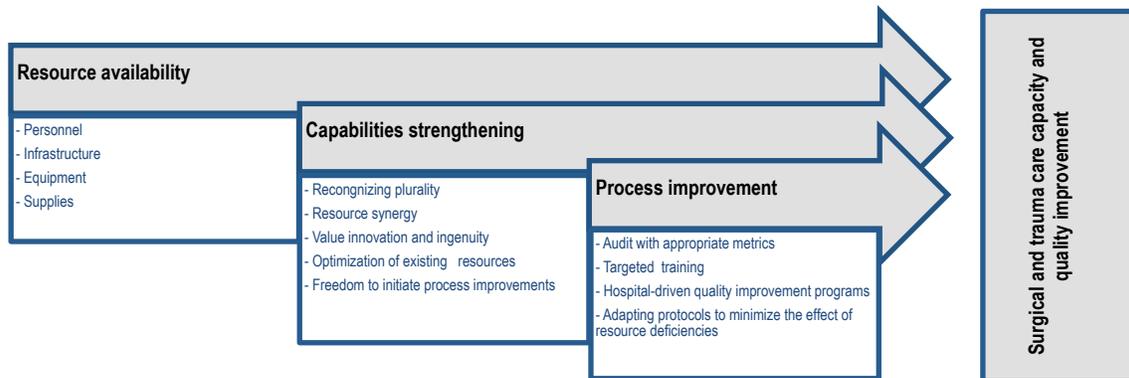
Rationale for amendment request

At the time of writing the proposal, I was developing a course for quality improvement for district-level hospitals in Ghana and monitoring and evaluating its impact by prospectively collecting audit filters (original Objectives 6 and 7). While this work continues, it is not immediately aligned with the matured theoretical and conceptual framework for assessing access and availability of safe, timely and affordable trauma care. Therefore, I would like to remove the original Objectives 6 and 7 and replace them with a new Objective 6 - 8 that better fits the progression of research with the proposal and utility of the multi-level assessments.

The new objectives include assessment of barriers to surgical care, including spatial access to care using tools that we developed and/or applied to surgery and trauma care from other fields. Objective 6 and 7 allowed assessment of the factors that prevent patients from seeking or reaching care in a timely manner when needed. Objective 8 is a capstone or actualization of the other assessments of access, facility-capacity, quality improvement, and data capture that were required to complete Objectives 1 – 5 and new Objectives 6 and 7. As mentioned above, the new Objective 8 entails performing a system-wide assessment using a novel World Health Organization toolkit that aids in: engaging stakeholders; identifying gaps in the emergency, surgical and trauma care system; and generating action priorities during a consensus-building working group meeting. After World Health Organization, Ghana Health Service, and Kwame Nkrumah University of Science and Technology approvals, this was completed in 2017 and the action priorities are being used to inform health policy and targeted interventions. This assessment is novel because, although piloted in process by the World Health Organization, it had not been piloted in its entirety at a national-level prior to our work in Ghana. Additionally, previous assessments of trauma care in low- and middle-income countries have predominantly focused on facility-based capacity and preparedness and have not considered the system within which they function and the population demand on that system.

Related changes to the conceptual framework

Original conceptual framework



The conceptual framework that I proposed is still helpful and is being used to inform our ongoing work; however, the relatedness of concepts contained within Objectives 1 – 6 is better illustrated with the following conceptual framework, which was developed as the work for this proposal was organized, performed, and reviewed.



In this conceptual framework, there are two main issues that relate to safe, timely, and affordable trauma care when needed. The first is access, or barriers, to care, and the second is availability of care.

While there are many individual barriers to accessing care, they can be categorized into three domains: acceptability – the willingness and sociocultural appropriateness of care; affordability – indirect and direct costs of care; and accessibility – ability to navigate contact with the health system and structural challenges to reaching care.

Availability of care is similarly complex, and related to a host of factors that can be broadly categorized into: governance and organization (e.g., leadership, incentivization schemes, emotional infrastructure, policies and protocols); financing; capacity and capabilities (e.g., infrastructure, physical and human resources, ability to function within an environment); data for quality and process improvement (e.g., data that allows monitoring, evaluation, and intervention); and preparedness for emergencies or disasters, or other shocks to the health system. In reality, these two main issues (i.e., access or barriers to care, and availability of care) are related;

however, I have created a somewhat artificial distinction between the two allow conceptualization of demand-side issues (i.e., access issues that are predominantly played out in the patients' environments) and supply-side issues (i.e., availability issues that are predominantly related to the health system).

The intersection of demand-side and supply-side issues can be considered capitalization in the form of access to safe, timely, and affordable care when needed; more specifically, capitalization can be considered the output generated from a set of costs for trauma care delivery (e.g., resources and functions) and need (i.e., demand); therefore, capitalization is the return on investment for minimizing barriers to care and optimizing care availability.

REFERENCES

1. Lozano R, Naghavi M, Foreman K, Lim S, Shibuya K, Aboyans V, *et al.*, Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010 *Lancet* 2012: 380; 2095-2128
2. Stewart B, Khanduri P, McCord C, Ohene-Yeboah M, Uranues S, Vega Rivera F, *et al.*, Global disease burden of conditions requiring emergency surgery *British Journal of Surgery* 2014: 101; e9-22
3. Bickler SN, Weiser TG, Kassebaum N, Higashi H, Chang DC, Barendregt JJ, *et al.*, Global Burden of Surgical Conditions. In: Debas HT, Donkor P, Gawande A, *et al.* editors *Essential Surgery: Disease Control Priorities, Third Edition (Volume 1)*, Washington (DC), 2015.
4. <http://vizhub.healthdata.org/gbd-cause-patterns/> 2015 May 27
5. Injuries and violence: the facts, Geneva, World Health Organization, 2010.
6. Mock C, Confronting the global burden of surgical disease *World journal of surgery* 2013: 37; 1457-1459
7. Carlson LC, Lin JA, Ameh EA, Mulwafu W, Donkor P, Derbew M, *et al.*, Moving from Data Collection to Application: A Systematic Literature Review of Surgical Capacity Assessments and their Applications *World journal of surgery* 2015: 39; 813-821

8. Mock C, Juillard C, Joshipura M, Goosen J, Strengthening care for the injured: success stories and lessons learned from around the world, Geneva, World Health Organization, 2010.
9. Mock C, Julliard C, Brundage S, Goosen J, Joshipura M, Guidelines for trauma quality improvement programmes, Geneva, World Health Organization, 2009.
10. Reynolds TA, Stewart B, Drewett I, Salerno S, Sawe H, Toroyan T, *et al.*, The Impact of Trauma Care Systems in Low- and Middle-Income Countries Annual review of public health 2017
11. Groen RS, Kamara TB, Dixon-Cole R, Kwon S, Kingham TP, Kushner AL, A tool and index to assess surgical capacity in low income countries: an initial implementation in Sierra Leone World journal of surgery 2012: 36; 1970-1977
12. Mock C, Nguyen S, Quansah R, Arreola-Risa C, Viradia R, Joshipura M, Evaluation of Trauma Care capabilities in four countries using the WHO-IATSIC Guidelines for Essential Trauma Care World journal of surgery 2006: 30; 946-956
13. Quansah R, Mock C, Abantanga F, Status of trauma care in Ghana Ghana medical journal 2004: 38; 149-152
14. Linden AF, Sekidde FS, Galukande M, Knowlton LM, Chackungal S, McQueen KA, Challenges of surgery in developing countries: a survey of surgical and anesthesia capacity in Uganda's public hospitals World journal of surgery 2012: 36; 1056-1065
15. Shah MT, Joshipura M, Singleton J, LaBarre P, Desai H, Sharma E, *et al.*, Assessment of the Availability of Technology for Trauma Care in India World journal of surgery 2014: 39; 363-372

16. Chao TE, Burdic M, Ganjawalla K, Derbew M, Keshian C, Meara J, *et al.*, Survey of surgery and anesthesia infrastructure in Ethiopia *World journal of surgery* 2012: 36; 2545-2553
17. Choo S, Perry H, Hesse AA, Abantanga F, Sory E, Osen H, *et al.*, Assessment of capacity for surgery, obstetrics and anaesthesia in 17 Ghanaian hospitals using a WHO assessment tool *Tropical medicine & international health : TM & IH* 2010: 15; 1109-1115
18. Gupta S, Wong E, Mahmood U, Charles AG, Nwomeh BC, Kushner AL, Burn management capacity in low and middle-income countries: A systematic review of 458 hospitals across 14 countries *International journal of surgery* 2014
19. Wong EG, Gupta S, Deckelbaum DL, Razek T, Kamara TB, Nwomeh BC, *et al.*, The International Assessment of Capacity for Trauma (INTACT): an index for trauma capacity in low-income countries *Journal of Surgical Research* 2014: 190; 522-527
20. Wong EG, Gupta S, Deckelbaum DL, Razek T, Kushner AL, Prioritizing injury care: a review of trauma capacity in low and middle-income countries *Journal of Surgical Research* 2014
21. Son NT, Mock C, Improvements in trauma care capabilities in Vietnam through use of the WHO-IATSiC Guidelines for Essential Trauma Care *International Journal of Injury Control and Safety Promotion* 2006: 13; 125-127
22. Son NT, Thu NH, Tu NT, Mock C, Assessment of the status of resources for essential trauma care in Hanoi and Khanh Hoa, Vietnam *Injury* 2007: 38; 1014-1022
23. LeBrun DG, Chackungal S, Chao TE, Knowlton LM, Linden AF, Notrica MR, *et al.*, Prioritizing essential surgery and safe anesthesia for the Post-2015 Development Agenda: operative

capacities of 78 district hospitals in 7 low- and middle-income countries *Surgery* 2014: 155; 365-373

24. Markin A, Barbero R, Leow JJ, Groen RS, Skow EJ, Apelgren KN, *et al.*, A quantitative analysis of surgical capacity in Santa Cruz, Bolivia *The Journal of surgical research* 2013: 185; 190-197

25. Moore L, Lavoie A, Bourgeois G, Lapointe J, Donabedian's structure-process-outcome quality of care model: Validation in an integrated trauma system *Journal of Trauma and Acute Care Surgery* 2014: 78; 1168-1175

26. Samuel JC, Tyson AF, Mabedi C, Mulima G, Cairns BA, Varela C, *et al.*, Development of a ratio of emergent to total hernia repairs as a surgical capacity metric *International journal of surgery* 2014: 12; 906-911

27. Hughes CD, McClain CD, Hagander L, Pierre JH, Groen RS, Kushner AL, *et al.*, Ratio of cesarean deliveries to total operations and surgeon nationality are potential proxies for surgical capacity in central Haiti *World journal of surgery* 2013: 37; 1526-1529

28. Weiser TG, Regenbogen SE, Thompson KD, Haynes AB, Lipsitz SR, Berry WR, *et al.*, An estimation of the global volume of surgery: a modelling strategy based on available data *Lancet* 2008: 372; 139-144

29. Stewart B, Wong E, Papillon-Smith J, Trelles M, Dominguez L, Basimyoneye-Kahutsi J, *et al.*, An analysis of cesarean section and emergency hernia ratios as markers of surgical capacity in low-income countries affected by humanitarian emergencies from 2008 – 2014 at Médecins Sans

Frontières Operations Centre Brussels projects PLoS Current
Disasters 2015

30. Strengthening emergency and essential surgical care and anaesthesia as a component of universal health coverage. In: Assembly WH editor EB136.R7, 2015.
31. Davies JI, Meara JG, Global surgery-going beyond the Lancet Commission Lancet 2015
32. Meara JG, Leather AJ, Hagander L, Alkire BC, Alonso N, Ameh EA, *et al.*, Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development Int J Obstet Anesth 2016: 25; 75-78
33. Ng-Kamstra J, Raykar N, Meara JG, Shrimpe MG, <http://blogs.worldbank.org/opendata/measuring-surgical-systems-new-paradigm-health-systems-strengthening> 2018 12/12
34. Global Reference List of 100 Core Health Indicators (plus health-related SDGs), Geneva, Switzerland, World Health Organization, 2014.
35. Debas HT, Donkor P, Gawande A, Jamison DT, Kruk ME, Mock CN, Essential Surgery. In: Jamison DT, Nugent R, Gelband H, *et al.* editors Disease Control Priorities, 3rd Edition, Washington, D.C., International Bank for Reconstruction and Development / The World Bank, 2015.
36. Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT, Essential surgery: key messages from Disease Control Priorities, 3rd edition The Lancet 2015
37. Dieleman JL, Yamey G, Johnson EK, Graves CM, Haakenstad A, Meara JG, Tracking global expenditures on surgery: gaps in knowledge hinder progress The Lancet. Global health 2015: 3 Suppl 2; S2-4

38. Poenaru D, Ozgediz D, Gosselin RA, Burden, need, or backlog: a call for improved metrics for the global burden of surgical disease *International journal of surgery* 2014; 12; 483-486
39. Bolkan HA, Hagander L, von Schreeb J, Bash-Taqi D, Kamara T, Salvesen Ø, *et al.*, The Surgical Workforce and Surgical Provider Productivity in Sierra Leone: A Countrywide Inventory *World journal of surgery* 2016
40. Kingham TP, Kamara TB, Cherian MN, Gosselin RA, Simkins M, Meissner C, *et al.*, Quantifying surgical capacity in Sierra Leone: a guide for improving surgical care *Archives of surgery* 2009; 144; 122-127; discussion 128
41. Stelfox HT, Bobranska-Artiuch B, Nathens A, Straus SE, Quality indicators for evaluating trauma care: a scoping review *Archives of surgery* 2010; 145; 286-295
42. Wesson HK, Bachani AM, Wekesa JM, Mburu J, Hyder AA, Stevens KA, Assessing trauma care at the district and provincial hospital levels: a case study of hospitals in Kenya *Injury* 2013; 44 Suppl 4; S75-80
43. Evans C, Howes D, Pickett W, Dagnone L, Audit filters for improving processes of care and clinical outcomes in trauma systems *The Cochrane database of systematic reviews* 2009; CD007590
44. Mock C, A Banner Year for Global Surgery: Now How to Make it Make a Difference on the Ground *World journal of surgery* 2015; 39; 2111-2114
45. Mock C, Quansah R, Kobusingye O, Goosen J, Trauma care in Africa: The way forward *African Journal of Trauma* 2014; 3; 3-10

46. Ng-Kamstra JS, Greenberg SLM, Abdullah F, Amado V, Anderson GA, Cossa M, *et al.*, Global Surgery 2030: a roadmap for high income country actors *BMJ Glob Health* 2016: 1; e000011
47. Donabedian A, The quality of care. How can it be assessed? *JAMA : the journal of the American Medical Association* 1988: 260; 1743-1748
48. Grocott MP, Galsworthy MJ, Moonesinghe SR, Health services research and anaesthesia *Anaesthesia* 2013: 68; 121-135
49. Sen A, *Commodities and capabilities* Amsterdam & New York, North-Holland, 1985
50. Sen A, *The Tanner Lecture on Human Values* Stanford University, 1979
51. Clark DA, *The Capability Approach: Its Development, Critiques and Recent Advances*, Swindon, UK, Global Poverty Research Group, 2014.
52. Sen A, *Development as freedom* New York, Oxford University Press, 2001
53. Grimes CE, Bowman KG, Dodgion CM, Lavy CB, Systematic review of barriers to surgical care in low-income and middle-income countries *World journal of surgery* 2011: 35; 941-950
54. Meara JG, Leather AJ, Hagander L, Alkire BC, Alonso N, Ameh EA, *et al.*, Global Surgery 2030: Evidence and solutions for achieving health, welfare, and economic development *Surgery* 2015: 158; 3-6
55. Dare AJ, Lee KC, Bleicher J, Elobu AE, Kamara TB, Liko O, *et al.*, *Prioritizing Surgical Care on National Health Agendas:*

A Qualitative Case Study of Papua New Guinea, Uganda, and Sierra Leone PLoS medicine 2016: 13; e1002023

56. Shiffman J, Smith S, Generation of political priority for global health initiatives: a framework and case study of maternal mortality Lancet 2007: 370; 1370-1379

57. Gajewski J, Bijlmakers L, Brugha R, Global Surgery - Informing National Strategies for Scaling Up Surgery in Sub-Saharan Africa Int J Health Policy Manag 2018: 7; 481-484

58. Stewart BT, Gyedu A, Abantanga F, Abdulai AR, Boakye G, Kushner A, Barriers to Essential Surgical Care in Low- and Middle-Income Countries: A Pilot Study of a Comprehensive Assessment Tool in Ghana World journal of surgery 2015

59. Ramirez M, Ford ME, Stewart AL, Teresi JA, Measurement issues in health disparities research Health services research 2005: 40; 1640-1657

60. Patel PB, Hoyler M, Maine R, Hughes CD, Hagander L, Meara JG, An opportunity for diagonal development in global surgery: cleft lip and palate care in resource-limited settings Plastic surgery international 2012: 2012

61. Guest GD, McLeod E, Perry WRG, Tangi V, Pedro J, Ponifasio P, *et al.*, Collecting data for global surgical indicators: a collaborative approach in the Pacific Region BMJ Glob Health 2017: 2; e000376

62. Ibrahim GM, Cadotte DW, Bernstein M, A framework for the monitoring and evaluation of international surgical initiatives in low- and middle-income countries PloS one 2015: 10; e0120368

63. Davies JF, Lenglet A, van Wijhe M, Ariti C, Perioperative mortality: Analysis of 3 years of operative data across 7 general

surgical projects of Medecins Sans Frontieres in Democratic Republic of Congo, Central African Republic, and South Sudan Surgery 2016: 159; 1269-1278

64. Stewart BT, Gyedu A, Quansah R, Addo WL, Afoko A, Agbenorku P, *et al.*, District-level hospital trauma care audit filters: Delphi technique for defining context-appropriate indicators for quality improvement initiative evaluation in developing countries Injury 2015

65. Hripcsak G, Bloomrosen M, Flatley Brennan P, Chute CG, Cimino J, Detmer DE, *et al.*, Health data use, stewardship, and governance: ongoing gaps and challenges: a report from AMIA's 2012 Health Policy Meeting J Am Med Inform Assoc 2014: 21; 204-211

66. Bolkan HA, van Duinen A, Waalewijn B, Elhassein M, Kamara TB, Deen GF, *et al.*, Safety, productivity and predicted contribution of a surgical task-sharing programme in Sierra Leone The British journal of surgery 2017: 104; 1315-1326

67. Stewart BT, Editorial Commentary on Bolkan *et al.* "The Surgical Workforce and Surgical Provider Productivity in Sierra Leone: A Countrywide Inventory" World journal of surgery 2016

68. Stewart BT, Gyedu A, Gaskill C, Boakye G, Quansah R, Donkor P, *et al.*, Exploring the Relationship Between Surgical Capacity and Output in Ghana: Current Capacity Assessments May Not Tell the Whole Story World journal of surgery 2018

69. Govindarajan V, Bagchi S, The Emotionally Bonded Organization: Why Emotional Infrastructure Matters and How Leaders Can Build It, Dartmouth College, 2009.

70. Rasmus DW, How Clinging to Core Competencies is Breaking Your Organization's HeartFast Company, Serious Insights, 2015.

71. Mock C, Joshipura M, Arreola-Risa C, Quansah R, An estimate of the number of lives that could be saved through improvements in trauma care globally World journal of surgery 2012; 36; 959-963