Establishing an obstetric critical care unit in a South African Tertiary Hospital

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DECLARATION

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Date: March 2016

This thesis is dedicated to my parents, Jane, Emelia and Jacob

SUMMARY

Life-threatening complications during pregnancy and childbirth may develop unexpectedly and can rapidly progress to organ failure and even death. Survival depends on quality emergency obstetric and critical care management. The limited critical care resources in South Africa often lead to maternal deaths that are potentially preventable. The incidence of patients admitted with severe acute maternal morbidity has progressively increased at the Tygerberg Academic Hospital. Even in this tertiary obstetric unit the required level of care was often not available in time to prevent further deterioration and preventable maternal mortality increased.

The volume of research specifically addressing the impact of obstetric critical care on maternal and perinatal outcomes is limited. There was also no specific guidance on obstetric critical care unit design, establishment and management. The ultimate objectives of this thesis were to establish and then demonstrate improved outcomes in critically ill obstetric patients with existing or developing organ dysfunction/failure, when managed in a dedicated level 2/3 obstetric critical care unit. The studies were performed in the labour ward at the Tygerberg Academic Hospital which serves as both a secondary (specialist care) and a tertiary (sub-specialist care) referral unit.

In order to quantify and clarify the need for level 2 and level 3 obstetric critical care in Tygerberg Academic Hospital, a structured, prospective, pre-establishment audit was designed and carried out using general intensive care organ dysfunction criteria as well as the indications for proposed management principles. Thereafter, a unique, detailed obstetric critical care unit design blueprint was developed and implemented with the establishment of the obstetric critical care unit within the labour ward. In order to test the blueprint the pre-establishment audit template was used prospectively to audit patients admitted to the obstetric critical care unit one year later. The data of the “Before OCCU” group were compared to the data of the “After OCCU” group. The results indicated that the two study groups were comparable on admission. The predefined indicated management was more often received in the “After OCCU” group compared to the “Before OCCU” group in terms of monitoring, advanced resuscitation and appropriate organ system support. The before and after comparison,

demonstrated a statistically significant decrease in maternal mortality for patients managed in the obstetric critical care unit.

The initial 302 patients managed in the obstetric critical care unit were also studied prospectively. The primary outcome measures were maternal morbidity and mortality. Forty-five percent of admissions were undelivered and 25% were HIV positive. Two thirds of admissions had severe organ dysfunction requiring level 2 obstetric critical care, while one third developed or had existing indications for level 3 obstetric critical care. The most common reasons for admission were pre-eclampsia, medical disorders, severe sepsis and massive haemorrhage. Intra-arterial lines were frequently used to guide resuscitation and administration of vaso-active drug infusions. Mask Continuous Positive Airway Pressure was utilised in pre-eclampsia patients with respiratory distress and pulmonary oedema, the intubation rate was only 12%. The overall maternal mortality was only 2.6%. The severe acute maternal mortality:mortality rate at the institution prior to the establishment of the obstetric critical care unit was one death in every five women admitted with severe morbidity, this decreased to one mortality in every 30 patients admitted with severe morbidity.

These studies demonstrated that the Obstetric Critical Care Unit provided effective care service which resulted in a significant reduction in mortality as well as very low mortality rate in women who suffered life threatening complications. The blueprint should be replicated in similar settings to decrease preventable mortality.

OPSOMMING

Lewensbedreigende komplikasies van swangerskap en geboorte kan skielik ontwikkel en dan vinnig oorgaan na orgaanversaking en selfs dood. Oorlewing hang af van kwaliteit nood-verloskunde en kritieke sorg behandeling. Die beperkte kritieke sorg hulpbronne in Suid-Afrika lei dikwels tot moederlike sterftes wat potensieël voorkombaar is. Die voorkoms van pasiënte wat met akute, erge moederlike morbiditeit opgeneem is, het voortdurend toegeneem by Tygerberg Akademiese Hospitaal. Selfs in hierdie tersiêre verloskunde eenheid was die nodige vlak van sorg met tye nie beskikbaar om verdere agteruitgang te verhoed nie, en het gelei tot voorkombare moederlike mortaliteit.

Die beskikbare navorsing wat spesifiek die impak van verloskunde kritieke sorg op moederlike en fetale uitkomste aanspreek, is beperk. Daar was ook geen spesifieke leiding in terme van die ontwerp, vestiging en bestuur van ‘n verloskunde kritieke sorg eenheid nie. Die einddoelwitte van hierdie tesis was die vestiging van so ‘n eenheid en om dan verbeterde uitkomste te demonstreer by kritieke siek verloskunde pasiënte met gevestigde of ontwikkelende orgaandisfunksie/versaking as hulle in ‘n toegewysde vlak 2/3 verloskunde kritieke sorg eenheid behandel is. Die studies is uitgevoer in die kraamsaal van die Tygerberg Akademiese Hospitaal wat dien as beide ‘n sekondêre (spesialis sorg) en ook ‘n tersiêre (sub-spesialis sorg) verwysingseenheid.

Ten einde die behoefte vir vlak 2 en vlak 3 kritieke sorg by Tygerberg Akademiese Hospitaal te bepaal en te verduidelik is ‘n gestruktureerde, prospektiewe, voor-vestiging oudit ontwerp en uitgevoer deur gebruik te maak van algemene kritieke sorg orgaandisfunksie kriteria sowel as die indikasie vir voorgestelde behandelings beginsels. Hierna is ‘n verloskunde kritieke sorg eenheid bloudruk ontwerp, ontwikkel en uitgevoer met die vestiging van ‘n OCCU binne die kraamsaal. Om die bloudruk te toets, is dieselfde templaat van die voor-vestiging oudit gebruik om prospektief die pasiënte te oudit wat een jaar later in OCCU toegelaat is. Die data van die voor-OCCU groep is vergelyk met die data van die na-OCCU groep. Die resultate het bevestig dat die twee studiegroepe vergelykbaar was met toelating. Die voorafbepaalde aangeduide behandeling is meer gereeld toegepas in die na OCCU groep in vergelyking met die voor OCCU groep in terme van monitering, gevorderde resussitasie en toepaslike orgaansisteem ondersteuning. Die voor- en na-vergelyking het ‘n statisties betekenisvolle verlaging in moederlike mortaliteit gedemonstreer by pasiënte wat in die OCCU behandel is.

Die eerste 302 pasiënte wat toegelaat en hanteer is in die nuwe eenheid, is ook prospektief nagevors. Primêre uitkomste was moederlike morbiditeit en mortaliteit. Vyf-en-veertig persent van die toelatings was tydens die voorgeboorte periode en 25% van die pasiënte was HIV positief. Twee-derdes van die toelatings het erge orgaan disfunksie gehad en vlak 2 verloskunde kritieke sorg benodig, terwyl een derde indikasies ontwikkel het of reeds indikasies gehad vir toelating tot vlak 3 verloskunde kritieke sorg. Die mees algemene redes vir toelatings was preëklampsie, mediese toestande, erge infeksie en massiewe bloeding. Intra-arteriële lyne was gereeld gebruik om leiding te gee gedurende resussitasie en ook gedurende die infusie van vaskulêre middels. CPAP (voortdurende positiewe lugweg druk) mbv gesigsmaskers is gebruik tydens respiratoriese nood as gevolg van preëklampsie met pulmonale edeem, en die intubasie syfer was slegs 12%. Die algehele moederlike mortaliteit was slegs 2.6%. Die berekende akute erge moederlike mortaliteit: sterfte verhouding voor die OCCU was een sterfte per elke vyf kritike siek toelatings. Na die vestiging van OCCU het dit gedaal na een sterfte vir elke 30 pasiente toegelaat met lewensbedreigende toestande.

Hierdie studies het gedemonstreer dat die OCCU effektiewe sorg verskaf het wat gelei het tot ‘n betekenisvolle vermindering in moederlike mortaliteit asook ‘n baie lae mortaliteit in vroue wat lewensbedreigende komplikasies gehad het. Hierdie bloudruk moet gedupliseer word in soortgelyke omgewings om die voorkombare moederlike mortaliteit te verlaag.

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ABBREVIATIONS

AIDS - acquired immune deficiency syndrome
a-line - arterial-line
APACHE - Acute physiology age chronic health evaluation
APH - ante-partum haemorrhage
ARDS - acute respiratory distress syndrome
ART - anti-retroviral therapy
BiPAP - bi-level positive airway pressure
BMI – body mass index
BP - blood pressure
CEmOC - comprehensive emergency care
COPD – chronic obstructive pulmonary disease
CPAP - continuous positive airways pressure
CVP - central venous pressure
EmOC - emergency obstetric care
HELLP - Hemolysis, Elevated liver enzymes, Low platelet count
HIV - human immunodeficiency virus
ICU - Intensive Care Unit
IV – intravenous
MDG - Millennium Development Goals
MMR - maternal mortality ratio
NCCEMD - National Committee for Confidential Enquiries into Maternal Deaths
NPR - non-pregnancy-related
NPRI - non pregnancy related infections
OCCU - Obstetric Critical Care Unit
PAC - pulmonary artery catheter
PPH - post-partum haemorrhage
RCA - Royal College of Anesthetists
RCOG - Royal College of Obstetricians and Gynecologists
RR - Respiratory rate
SAMM - Severe Acute Maternal Morbidity
WHO – World Health Organization

CHAPTER 1: INTRODUCTION

1.1 Context

The death of a mother (maternal mortality), who dies young due to pregnancy complications, is one of the cruellest events imaginable. The impact of such a tragedy on her surviving baby, children, partner and family can be devastating (WHO, 1999). Maternal mortality is defined as "The death of a woman while pregnant or within 42 days after termination of pregnancy, irrespective of the duration or site of pregnancy, from any cause related to or aggravated by pregnancy or its management but not from accidental or incidental causes" (WHO, 1999). At the United Nations Millennium Summit the leaders of the 194 Member States reached consensus on working to achieve the 8 Millennium Development Goals (MDG) to reduce poverty focusing on improving critical economic, health and social priorities by 2015. One of the priorities was to the implementation of interventions to decrease maternal mortality (UN MDG, 2005). Goal 5 requires the reduction of maternal mortality by three-quarters between 1990 and 2015. Indicators 5A (maternal mortality ratio) and 5B (proportion of births attended by skilled health personnel) are used to measure the progress of countries towards achieving Goal 5 (UN MDG, 2005). The global effort towards reaching the MDG development goals has gathered momentum. The United Nations and WHO reported a global reduction in maternal mortality from maternal mortality ratio (MMR) of 400 deaths per 100 000 deliveries (MMR) to 210, however many obstetrics services throughout the world are currently grappling with maternal mortality (Saving Mothers, 2012; WHO, 2014).

During recent years, the global MDG focus has increasingly highlighted the fact that poor progress is being made towards reaching Goal 5 (improved maternal health) in sub-Saharan Africa (Blaauw et al., 2010; Hogan et al., 2010). In sub-Saharah Africa the risk of pregnancy related mortality is 1:6, On the other hand in Northern Europe the risk of pregnancy related mortality is 1:30 000 (Bhutta et al., 2012).

In this Africa region the maternal mortality ratio (MMR) only slightly decreased over more than two decades from 850 maternal deaths per 100 000 live births in 1990 to 500 deaths per 100 000 live births in 2013. Significant progress had been made by Northern Africa, Eastern and

Southern Asia with a reduction of around 65% in maternal deaths since 1990 (UN, 2013). Moving to developing countries – the MMR is estimated to be 190 in India, 45 in Egypt and 69 in Brazil. The MMR in Kenya is 400 (WHO, 2014). The South Africa Health Review of 2010 states that "The evidence is that South Africa is definitely not on track to achieve MDG 5 and that maternal mortality has actually increased since 1990 (Theron, 2012; Saving Mothers, 2012).

In developed countries/regions such as the United Kingdom, the latest MMR is 11.39/100 000 maternities. There was a significant reduction in this MMR when compared to the preceding triennium (p=0.02) (CMACE, 2011). In this report it was highlighted that there were avoidable factors present in 70% of direct deaths and 55% of the indirect maternal death cases. In order to further decrease mortality ten recommendations were made. In terms of quality of care, recommendations were made to improve skills in advanced life support, early recognition and management of severely ill pregnant or post-partum women. The importance of "early call for help" from anaesthetists and intensivists was highlighted. It is disturbing to note that the MMR in the United States increased from 12 maternal deaths/100 000 deliveries during 2000 to 28 during 2013 (WHO, 2014).

In South Africa an accurate MMR is not available. This is due to the fact that the denominator (total births in South Africa) is still not clearly defined. For this reason the analysis in South Africa reflects a MMR. A concerning fact is that the MMR in South Africa has increased. In 1990 this figure was 120, but has risen to an institutional MMR of 154 according to the National Committee for the Confidential Enquiries into Maternal Deaths (Blaauw et al., 2010; Saving Mothers, 2015). However, the figure is actually estimated to be higher (310) by other sources (Bradshaw & Dorrington, 2012). In the Western Cape Province of South Africa, where the total number of deliveries can be more accurately determined than in the rest of South Africa, the MMR is 77.6 (Saving Mothers, 2012). By comparison, this figure was 38.1 during 1990-1992 (Theron, 1996).

One of the successful interventions implemented in Southern and Eastern Asia to decrease maternal mortality was the WHO recommendation that basic emergency obstetric care (EmOC) must be implemented in all obstetric facilities. EmOC consists of basic signal functions such as: ability to administer IV antibiotics, anticonvulsants and oxytocics; ability to perform assisted delivery and manual removal of the placenta. The second requirement recommendation is that comprehensive emergency care (CEmOC) must be accessible which consists of the ability to perform caesarean section and blood transfusions (WHO, 2014). In South Africa both EmOC and CEmOC have been increasingly implemented in health care facilities. In spite of these interventions the MMR in South Africa is still increasing. Two important reasons associated with the increased MMR in the Western Cape were the HIV epidemic (and associated complications) and the migration of pregnant women with medical risk factors from other provinces with limited health infrastructures. These reasons will be expanded apon later. The obstetric patient's survival will then be determined by the quality of more advanced life saving skills and access to quality emergency management (Pattinson, 2013; Perinatal and maternal outcomes, 2011). The fact is that even in developed countries such as the United Kingdom and United States there are still many maternal deaths that can be prevented. In a Southern England multicentre study of obstetric admissions to 14 general intensive care units it was disturbing to discover that nearly two thirds of the maternal mortalities occurred outside of the Intensive Care Unit (ICU) (Hazelgrove et al., 2001). This means that even in countries with adequate health care resources pregnant women may present with early warning signs of imminent complications and can rapidly deteriorate and die even before the intensivists can assist in management.

It is of utmost importance that women at risk must be identified and managed appropriately. "Near miss" maternal mortality or Severe Acute Maternal Morbidity (SAMM) is more common than maternal mortality (Mantel et al., 1998; William et al., 2014). The current definition of SAMM is: "a woman who nearly died but survived a complication that occurred during pregnancy, childbirth or within 42 days after termination of pregnancy (WHO, 2014). Because SAMM cases share many characteristics with maternal deaths (Cocket et al., 2003; Pattinson & Buchman, 2003; Say et al., 2009; Baskett, 2008; Tuncalp et al., 2012), understanding and managing SAMM (organ dysfunction/failure) will help to decrease and/or prevent maternal mortality. To achieve optimal management of women with SAMM, principles of critical care management need to be applied. It goes without saying that such principles are best practiced within an organised and dedicated unit. In developed countries, general surgical, medical and sometimes obstetric critical care units with highly trained staff are easily accessible. However, in developing countries the incidence of SAMM is increased compared to developed countries and where the conversion rate of SAMM to maternal mortality is much higher (Mantel et al., 1998; Say et al., 2009), early access to advanced emergency care or admission to any type of

ICU is unfortunately very limited. In South African public hospitals the ICU bed per population number is as little as 1:42 000 compared to Europe where the average ICU bed per population varies from 1:3427 to 1:8700 Naidoo et al., 2013; Rhodes et al., 2012). The majority of tertiary academic hospitals have a limited number general surgical and medical ICU beds available. Critically ill obstetric cases therefore have to compete with all other general cases for admission into these ICUs (Mathiva, 2002).

Innovative changes such as the implementation of step-down units, intermediate care and high care units will enhance ICU capabilities and potentially decrease the need for ICU beds (Naidoo et al., 2013).

Since 1998, South Africa has audited all maternal deaths through a statutory regulation. In the two latest triennial reports lack of intensive care beds was identified as an important contributing factor to maternal mortality (Saving Mothers, 2008; Saving Mothers, 2012). To reduce mortality in obstetric patients with serious complications that result in organ dysfunction and or in failure, survival will be determined by rapid access to adequate skilled care in an adequately resourced facility (Pattinson, 2013). In this regard, it is interesting to note that in 2005, there was only one dedicated Obstetric Critical Care Unit (OCCU) in the entire country of South Africa. This unit was based at the Groote Schuur Tertiary Academic Hospital of the University of Cape Town. The Western Cape Province of South Africa provides the most comprehensive provincial health service in the country, as reflected by the MMR. The causes of morbidity and by implication mortality have been clearly audited over many years. In order to substantively address this problem, a number of senior obstetricians and an obstetric anaesthetist working in the Tygerberg Tertiary Academic Hospital (linked to Stellenbosch University), identified and demonstrated the need to establish an OCCU within the labour ward of this hospital. As part of that process the literature was reviewed to find guidance on the following key aspects: a) to access available evidence of improved outcomes through the establishment of such a unit, b) to find guidance in the establishment of such a unit, and c) to identify relevant admission and discharge criteria.

1.2 Aims and description of the study

The objective of this study was to demonstrate a decrease in institutional maternal mortality and morbidity by providing on site emergency and critical care through the establishment of an Obstetric Critical Care Unit within the labour ward of a South African Tertiary Hospital.

The first part of this study (Chapter 2) provides a comprehensive literature overview on the definitions of obstetric critical care, the various types of ICUs, various models for these ICUs and their efficacy in managing SAMM and preventing maternal mortality. Chapter 3 begins by describing a prospective pre-establishment audit performed to confirm the number of patients with significant morbidity requiring advanced obstetric care within the service. Using this information a blueprint was constructed and implemented. This blueprint for the establishment of an OCCU within the labour ward of a tertiary academic hospital in South Africa, as well as modifications thereof is carefully described in Chapter 3. In Chapter 4 the testing of this blueprint is described. This was performed by comparing a prospective audit of cases qualifying for obstetric critical care (three months prior to the establishment of the OCCU) to patients admitted to the OCCU during the corresponding period of months in the following year. Chapter 5 provides a detailed audit of all cases admitted to the OCCU in the first 15 months of its existence. Finally Chapter 6 draws conclusions from the dissertation and offers insights on the way forward. In particular, how this model could be applied in other hospitals of South Africa and/or other hospitals in developing or certain developed countries.

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CHAPTER 2: OBSTETRIC CRITICAL CARE AND OBSTETRIC CRITICAL CARE UNITS

Obstetric critical care is a field that remains unevenly researched. There is only limited research evidence that specifically addresses the impact of obstetric critical care on maternal and perinatal outcomes (ACOG, 2009; Wheatly, 2010). A critically ill patient can be defined as a patient with impending, developing or established significant organ dysfunction, which may lead to long term morbidity or death (Ananth & Smulian, 2010). There is currently no uniform definition for obstetric critical care or OCCU's.

The principle of grouping acutely ill patients together in a dedicated area with the necessary, infra-structure, monitoring, doctors with appropriate knowledge and skill and adequately trained nursing staff has been shown to improve outcomes in general critical care. When this principle is applied to obstetrics it may also improve maternal and foetal outcomes (Mabie & Sibai, 1990; Zeeman et al., 2003; Scott & Foley, 2010). In such a dedicated area, patients can be resuscitated and observed. The underlying pathology can be identified, treated and supportive care for the patient can be provided during the critical event (Baskett, 2008, ACOG, 2009).

In a recent review of 33 descriptive case series of obstetric patients admitted to general intensive care units, it was found that nearly 80% of the admissions were during the postnatal period. The leading primary causes of critical care admission to Critical Care Units were hypertensive disorders, bleeding, sepsis and medical disorders (Ananth & Smulian, 2010).

The aim of obstetric critical care is to ensure adequate oxygen delivery to the critically ill mother and fetus during the ante- and postnatal periods. General critical care and obstetric critical care principles include early goal directed resuscitation, monitoring and organ system support in the critically ill obstetric patient (Price et al., 2008). In a search of the Cochrane Library database no current reviews assessing evidence of the impact of obstetric critical care on maternal and foetal outcomes were found. The importance of critical care and the need for involvement of the anaesthetists to assist with obstetric critical care principles and critical care monitoring procedures, forms part of the expert opinion recommendations in the "Bacterial Sepsis in pregnancy" Green-top Guideline (RCOG, 2010). The necessity of involving critical care physicians to ensure safe transfer to High Dependency Units (HDU) and Intensive Care Units

(ICU) when indicated is also recommend in the multidisciplinary document from the United Kingdom: "Providing equity of critical care and maternity care for the critically ill pregnant woman". This document was compiled by the Maternal Critical Care Working Group consisting of nominated experts from the following organizations: RCOG, RCA, Liverpool Women's NHS Trust, Obstetric Anaesthetist Association, British Maternal Foetal Association and the Intensive Care Society using evidence based on expert opinion. The application of critical care principles in emergency obstetric management is discussed (Maternal Critical Care Working Group, 2011). This document also emphasises the importance of early recognition and management of the critically ill parturient and early transfer to appropriate critical care units when indicated. Similarly, early access to the appropriate level of critical care management and help from an intensivist is one of the recommendations in the UK Saving Mothers Report in an attempt to improve maternal outcomes (CMACE, 2011).

In addition to the abovementioned expert opinions, there are now large descriptive case series published that demonstrate low maternal morbidity and mortality rates when critically ill obstetric patients are admitted timeously to critical care facilities (Mabie & Sibai, 1990; Zeeman et al., 2003; Baskett, 2008). It is important to note that the publications from developed countries report very low maternal mortality rates 0-2.35% in critically ill obstetric patients (Lapinsky et al., 1997; Munnur et al., 2005). A case series of critically ill obstetric patients admitted to a dedicated obstetric intensive care unit in a South African tertiary hospital, over one year reported 258 admissions and 7 maternal deaths (Johanson et al., 1995). This result was achieved against a background maternal mortality rate of 38 in the Western Cape Province of South Africa (Theron, 1996). Compared to a similar North American case series of critically ill obstetric patients admitted to a dedicated obstetric intensive care unit (Mabie & Sibai, 1990), the maternal mortality rate and other outcomes were comparable (see Tables 3 & 4).

Evidence based on studies using quasi-experimental and observational designs supports the WHO view that EmOC must be a critical component of any strategy to decrease maternal mortality (Paxton et al., 2005). Comprehensive early emergency obstetric care has been implemented in countries such as Egypt and Sri-Lanka and maternal mortality rates in these countries decreased compared to 1990 (Theron, 2012). It is however important to understand that improvements in country health economics and changes in the general health care systems over the past 24 years also contributed to decreased mortality. CEmOC must be an integral part of any obstetric facility and care must also be taken to develop lifesaving skills and access to more advanced emergency care and critical care.

In a comprehensive review (including 33 descriptive studies) Ananth & Smulian evaluated the perinatal outcomes of women admitted to general critical care units (2010). In this review, the overall perinatal mortality rate was 25.6%. This high figure highlights the importance of considering the fetus when managing the critically ill pregnant patient. The provision of early critical care when the patient is still pregnant, thereby providing a favourable intra-uterine environment may possibly improve perinatal outcomes (Price et al, 2008; Garite, 2010).

The correct location of a dedicated obstetric critical care unit, ie within the labour ward, offers many advantages such as early access to emergency care on site and critical care for both mother and fetus. The reported studies using this location of the obstetric critical care unit report favourable outcomes (see Table 4) (Mabie & Sibai, 1990; Johanson et al. 1995; Amorim et al., 2006; Ryan & Hamilton, 2000). A characteristic of these studies is that the admissions demonstrated severe disease (meriting critical care admission) with resultant low maternal mortality.

There is little detailed guidance in the literature on the establishment of an OCCU. In addition, the Critical Care or Intensive Care Societies of Australia, the United Kingdom and the United States of America provide guidance on general critical care but no specific guidance on OCCU's. Locally, the South African Department of Health does not even mention obstetric critical care in their Critical Care policy (DOH, 2007).

Tygerberg Tertiary Academic Hospital in the Western Cape Province of South Africa has experienced a continuous increase in the number of complicated obstetric admissions and deliveries particularly after 2004. This increase was accompanied by an increase in maternal mortalities during the 2004-2005 period at this tertiary institution. Since 1998 all maternal deaths in South Africa have been reported and assessed by selected doctors and midwives. An important goal of such assessment is the identification of avoidable factors. A key administrative avoidable factor regularly reported is the lack of critical care facilities in as many as one in five maternal deaths (Saving Mothers, 2008; Saving Mothers, 2012). In South Africa, ICU resources account for only 1% of all acute beds. In the UK "Standards for Intensive Care" document it was recommended that ICU resources should be at least 8% of all acute beds (Intensive Care Society, 2012). To further demonstrate the acute shortage of critical care beds in South Africa it was found that in the Eastern Cape province public health care service there is only one ICU bed available per 75 000 people (Naidoo et al., 2013). By contrast in a prospective audit of critical care beds per population in Europe during 2012, the critical care bed: head population in Germany was one ICU bed:3425 people and on average 1:8700 in Europe (Rhodes et al., 2012).

With the proceeding paragraphs as broad introduction to provide the context of the study, the author will now review the literature in greater detail. To do this, the following databases were searched: Medline, Scopus, Cochrane Library, issue 2 and issue 4, Cochrane pregnancy and Childbirth Group's Trial Groups' Trial Register and the Cochrane Effective practice and Organisation of care Group's Trial Register. ACOG, RCOG and Intensive Care Societies of the United States of America, the United Kingdom, UK Maternal Critical Care Working Group. Australia and South Africa as well as the RCOG Green-top Guidelines. The following MeSH headings were used: Obstetric Critical Care, Maternal Mortality, Maternal Morbidity, Intensive and High Dependency Care, Obstetric Intensive Care Units, High Care Units, High Dependency Units and Intermediate Care Units. Intensive care and Obstetrics, Obstetric Critical Care Epidemiology, Maternal Mortality Ratio and Critical Care; Severe Acute Maternal Morbidity and Obstetric Critical Care. Obstetric Critical Care Definitions, Obstetric Critical Care Classification and Levels of Critical Care. Establishing Obstetric Critical Care Units, Blueprints for Obstetric Critical Care Units and Guidance for Obstetric Critical Care Units. Appropriate chapters in obstetric critical care textbooks were studied.

The literature will be described under the following headings:

1. Defining levels of critical care, organ system support and the applications to obstetric critical care.
2. Classification system for dedicated OCCU's.
3. Models of critical care units.

4. Evidence for improved outcomes in general ICU's and OCCU's:
   4.1 Obstetric admissions to general ICU's.
   4.2 Obstetric admissions to dedicated critical care units in labour wards including described intensive care, high dependency care and intermediate care units.
5. Guidance for the establishment of an OCCU.

2.1 Defining levels of critical care, organ system support and the applications to obstetric critical care

SAMM, as defined by Mantel, et al. in 1998, is a modern term used within this field. The clinical criteria used in this publication, were specific organ based dysfunction or failure and management-based criteria such as ICU admission or peri-partum emergency hysterectomy (Mantel et al., 1998). SAMM criteria overlap with critical care criteria and are familiar to clinical obstetricians. Monitoring of SAMM or "near miss" maternal death can also be used as a valuable tool to assess the quality of maternal care (Say et al., 2009). Combining general critical care definitions and SAMM the following definition is proposed for obstetric critical care: "A critically ill obstetric patient can be defined as an antenatal, intra-partum or post-partum (42 days) critically ill patient with impending, developing or established significant organ dysfunction, which may lead to long term morbidity or death" (Ananth & Smulian, 2010).

Understanding the definitions of adult levels of critical care and different levels of general critical care units is essential to help to identify the critically ill obstetric patient and apply this knowledge to obstetric critical care (ACOG, 2009; Naidoo et al., 2013; Sultan et al., 2013).

Examples of specific definitions for Intensive Care and High Dependency Care Units are given in Table 1.

Table 1: Defining Intensive Care Units and High Dependency Care Units

ICU (Intensive Care Unit)	HDU (High Dependency Care Unit)
Patients requiring advanced respiratory support (intubation and mechanical ventilation).	CPAP (continuous positive airway pressure) or uncomplicated non-invasive mask ventilation.
Patients requiring support for two or more organ systems (multi-organ failure).	Patients requiring support for a single failing organ system, excluding advanced respiratory support.
Patients with chronic impairment of one or more organ systems sufficient to restrict daily activities and who require support for an acute reversible failure of another organ system.	Patients no longer needing ICU care, but not well enough to be returned to a general ward. Post-operative patients who need close observation.

Guidelines for Admission to and Discharge from Intensive Care and High Care Units (Critical Care Society (UK), 1996)

2.2 Definitions of organ system monitoring and support

2.2.1 Advanced respiratory support

2.2.1.1 Mechanical ventilatory support excluding mask continuous positive airways pressure (CPAP) or non-invasive (e.g. mask) ventilation.

2.2.2 Basic respiratory monitoring and support

2.2.2.1 The need for more than 40% oxygen via fixed performance mask.

2.2.2.2 The possibility of progressive deterioration to the point of needing advanced respiratory support (see above).

2.2.2.3 Patients recently extubated after a prolonged period of intubation and mechanical ventilation.

2.2.2.4 Patients who are intubated to protect the airway, but needing no ventilatory support and who are otherwise stable.

2.2.3 Circulatory support

2.2.3.1 Need for vasoactive drugs to support arterial pressure or cardiac output, as well as for circulatory instability of any cause or to manage hypertensive crises.

2.2.3.2 For patients resuscitated following cardiac arrest that cannot be placed in the main ICU.

2.2.4 Neurological monitoring and support

2.2.4.1 Central nervous system depression, from whatever cause, sufficient to prejudice the airway and protective reflexes.

2.2.5 Renal support

2.2.5.1 Patients requiring haemodialysis or haemofiltration.

[Categories of Organ System Monitoring and Support (UN DOH, 1996)]

In 2009 the UK Intensive Care Society proposed that the term critical care should replace the terms of intensive care, high dependency care, high care, intermediate and step down care. Critical care must be defined according to the level of critical care (0-3) required by the patient and the level of care can be provided at different locations based on the level of care required and the available resources. This concept supports the principle of critical care without walls (Wheatly, 2010). It however also remains important to provide adequate classification of critical care units to insure that the patient receives the appropriate care in the appropriate facility.

The proposed levels of critical care for adults are summarized as follows: level 0 critical care can be provided in a normal ward, level 1 critical care consists of hourly monitoring in patients at risk of deterioration (step down care area), level 2 critical care entails the provision of continuous monitoring in patients with one organ system failure or dysfunction and includes intra-arterial blood pressure monitoring (high dependency care unit or area), level 3 critical care includes mechanical ventilation and two or more organ systems failure (intensive care unit).

The art of effective emergency obstetric care is a thorough systemic evaluation of the obstetric patient to identify abnormal physiology, ascertain the underlying cause and then attempt to correct the underlying condition while providing supportive care for both mother and fetus. In Scotland, a developed country, Brace et al., identified 196 women with SAMM out of 51165 deliveries (< 1%) of whom only four died (2004). However, the SAMM:maternal mortality conversion rate in a developing country such as Nigeria, was high (1:0.8) (Okafor, 2004). In a South African study the SAMM:mortality conversion rate was 3.3:1 (Vandecruys & Pattinson, 2002). SAMM may therefore be used as a marker of critical illness and any obstetric patients with organ system dysfunction must stabilised and admitted to a unit with appropriate care.

2.3 Classification system for dedicated Obstetric Critical Care units

Dedicated obstetric critical care unit descriptive case-series were described in the literature the respective units described their experience of obstetric patients admitted to their specific units. It is important to attempt to clarify definitions and recommend a more uniform classification of obstetric critical care units currently described as intensive care units (Johanson et al., 1995; Mabie & Sibai, 1990), intermediate care units (Zeeman et al., 2003), obstetric critical care units (Langenegger et al., 2012), obstetric high dependency units (Saravanakumar et al., 2008). In the United Kingdom the Department of Health and Intensive Care Society recommended a classification of critically ill patients according to the clinical need of the patient. In July 2011 the Joint standing Committee of the Royal College of Obstetricians and Gynecologists (RCOG) and the Royal College of Anesthetists (RCA) published a report recommending that critically ill women should receive the same standard of care for both their pregnancy-related and critical care needs provided by relevant professionals whether these are provided in a maternity or general critical care setting. This classification system can be applied to different levels of care that the individual patient requires. The proposed levels of care range from 0 (normal ward care) to level 3 (ICU care) (Sultan et al., 2013). However in the UK most of level 3 intensive care is provided in a general ICU. In many hospitals in the UK a separate obstetric ICU is not a practical use of resources based on factors such as appropriateness of population size. In addition, the number of patients requiring level 2 obstetric care which can be provided in a high care dependency unit or a labour ward unit remains unclear (Sultan et al., 2013). It is possible to provide safe level 3 care in a dedicated OCCU where the principal care providers are maternal foetal medicine specialists and anaesthetists, however there must be indications for transfer to an on-site general ICU; for example multi organ dysfunction syndrome (Mabie & Sibai, 1990; Johanson et al., 1995). Mabie and Sibai retrospectively calculated that an incidence of 1% (200) of the total deliveries (22651) in their Texan tertiary hospital's referral area was adequate to justify a stand alone Obstetric ICU (1990). In other countries with limited ICU resources it is often required of a level 2, level of care provided in a labour ward setting, to upgrade to ICU care which includes mechanical ventilation and failure of two organ systems (Langenegger et al., 2012). This type of care including the qualification criteria for a specific level of critical care is not adequately specified or defined in the RCOG and RCA report. (The following proposed classification system for obstetric critical care (Table 2) is a combination of intensive care societies, of the United Kingdom, Australia and the United States of America, South Africa and the Joint Standing Committee of the RCOG and RCA:

Table 2: Recommended functions at various levels of obstetric critical care units

	OCCU (level 1)	**OCCU (level 2)**	**OCCU(level 3)**
Older terminology	Step-down care	Intermediate care, high dependency care	Intensive care, Obstetric Intensive care
Medical Care provider	Obstetrician consultant care	Obstetrician or MFM* Anaethetist on call for obstetric theatre. Multidisciplinary consultation	Obstetrician with experience in critical care)/ MFM* specialist. Anaesthetist, Intensivist available for consultation
Nursing Care	Midwife	Midwife with critical care experience	Critical care Nurse with midwivery background Midwife with critical care experience
Monitoring	Hourly vital observations. SaO2, Intake output Arterial-line	Arterial-line(a-line), central venous pressure catheter (CVP), ECG, SaO2	Pulmonary artery catheter (PAC), cardiac output A-line, CVP, ECG, SaO2
CVS Support	Oral and bolus IV anti-hypertensive.	Infusion of an anti-hypertensive IV nitrates	IV infusion anti-HT, IV nitrates, Inotropes
Respiratory support	40% O2 mask and Respiratory rate(RR) <30	RR>30 on 40% O2 or FiO2>40% Non-invasive support Continuous positive pressure (CPAP), Bi-level positive airway pressure (BiPAP)	Emergency intubation and ventilation capacity (short term), refer to general ICU. Manage complicated ventilation short term when no general ICU bed.
Renal support	No dialysis	Dialysis done by renal team in renal unit	Dialysis done by renal team in OCCU
Organ system failure	At risk of organ dysfunction for monitoring	Single organ system failure	Single organ system failure and another organ system dysfunction. Capacity to stabilize, manage and transfer two organ systems failure (MODS+, ALI#, ARDS^)

**Maternal Foetal Medicine subspecialist, [+]Multiple organ dysfunction syndrome, ^Adult respiratory distress syndrome, [#]Acute lung injury*

2.4 Models of critical care units

There are two management models for general critical care, namely Open and Closed Units. In the Closed Unit the patient is transferred to the specific ICU. The dedicated ICU team takes over responsibility of the patient while members of the multi-disciplinary specialties are consulted when necessary. In the Open Unit a surgeon, physician, obstetrician, anaesthetist or pediatrician admit their patient into an open ICU. The admitting doctor maintains responsibility for the management of patient. The Closed Unit has the advantage of a clinical director managing the unit and influence standard of care. Clinical care is provided by an intensivist or fellow on a 24 hour basis. Closed models have been shown to have improved clinical outcomes with lower morbidity and mortality and shortened length of hospital stay (ACOG, 2009; Intensive Care Society 1997). Foley et al. describes the concept of a virtual ICU where critical care support can be provided out of the ICU by an intensivist team at the patient's location for example in the labour ward (Scott & Foley, 2010; Mathiva, 2002). A Hybrid of the closed ICU system may be possible for an OCCU in South Africa with limited resources. During normal working hours the medical director or Obstetrician with an interest in Maternal Medicine will triage, admit and decide on patient management. After-hours the on call obstetric consultant and registrar will be primarily responsible for patient management. Critical Care support when needed may be provided by the labour ward theatre anaesthetic registrar. Involving anaesthetists in obstetric critical care patient management may improve maternal outcomes in Obstetric Critical Care. It is valuable when critically ill women or women at risk of critical illness can be assessed in the antenatal period in order to formulate an anaesthetic and combined critical care plan (Plaat &Wray, 2008).

2.5 Evidence for improved outcomes in general Intensive Care Units and Obstetric Critical Care Units

Evidence from descriptive case-series reports, is that the management of patients at risk of morbidity or with existing organ dysfunction in a general ICU or OCCU is associated with low maternal morbidity and mortality (Ananth & Smulian, 2010; DOH, 2007; Mabie & Sibai, 1990; Johanson et al., 1995; Zeeman et al., 2003; Ryan et al., 2000).

2.5.1 Obstetric admissions to general Intensive Care Units

It may be advantageous to admit patients with pre-viable fetuses and postpartum cases to a general ICU. The transfer of obstetric patients to a general ICU is indicated when the duration of critical care is expected to be prolonged. The concept of prolonged admission is however relative to the specific requirements of the patient, for example in the case of ventilation a prolonged duration may be regarded as greater than 48 hours. Other indications are when patients need mechanical ventilation inotropic support or organ system support of more than one failing organ. Under these circumstances, general ICU is the best option, because of the advantages of available critical care staff and advanced critical care interventions. Management of critically ill patients by intensivists has been shown to decrease mortality in the general population (ACOG, 2009). The same has not been shown specifically to be true for obstetric patients.

In a large systematic review of obstetric admissions to general ICUs, Ananth and Smulian included 33 studies published between 1990 and 2006 involving 1 955 111 deliveries. The overall obstetric-related admission rate to ICU in the review was 0.07-0.89%. This variation was explained in terms of different populations, tertiary hospitals with large catchment areas receiving more high-risk patients, and different admission criteria. The reported maternal mortality rate for critically ill obstetric patients admitted to a general ICU in this review was 8.4% (0-33%) (2010). There were marked differences in terms of patient morbidity and mortality between developed and developing countries after admission to critical care units. This is further illustrated by the following publications. In a tertiary hospital in Canada, Lapinsky et al. described 65 obstetric admissions to a general ICU. There were 25 000 deliveries in the referral population during the study period. The ICU admission rate was only 0.26% of deliveries and there were no maternal deaths (1997). However, in a case series from Ibidan, Nigeria, obstetric admissions to the hospital's general ICU from 1997-2002 were described. There were 6 544 deliveries in the referral region of the hospital during the study period. Eighteen obstetric cases were admitted to the general ICU (0.28%) of whom six women died (ICU death rate was 33%) (Okafor, 2004). However, it has been stated that up to 8% of the obstetric population need admission for critical care compared to 0.8% in the USA (ACOG, 2009; Okafor 2007; Mabie & Sibai, 1990).

In a Brazilian case series Oliveira Neto et al. described the outcomes of 673 patients admitted with SAMM to a general ICU in a women's hospital. The majority of patients required only level 2 critical care and there were 18 deaths reported. This demonstrates the advantage of early recognition of SAMM and early transfer to a critical care unit (Oliveira Neto et al., 2009).

A further study compared developed and developing country outcomes. The obstetric outcomes of women admitted to a general ICU in Texas, USA and women admitted to a general ICU in Mumbai, India, were compared by Munnur et al. (2005). King Edward Memorial Hospital in Mumbai admitted 754 obstetric patients to the general ICU from 1992 to 2001. The maternal mortality was high at 25% while foetal mortality was reported as 51%. These outcomes were compared to 174 obstetric patients admitted to a general ICU in the Texas hospital during the same period. Maternal mortality in the Texas hospital was much lower at 2.3%, while the foetal mortality figure was 13%. This difference may be due to the different populations, or poor attendance of antenatal care at the Mumbai Hospital. Another important difference is the fact that patients are often admitted later in the course of organ failure, due to the limited ICU resources (Munnur et al., 2005).

In a South African hospital, Platteau et al. described admissions to the general ICU during 1992. There were 20 000 deliveries during the study period. Of these 80 women (0.4%) were admitted for ICU care. Seventeen women died (maternal mortality – 21.3%). Stated differently the ICU admission rate was four women/1 000 deliveries and the death: transfer ratio was high at 1:5 (1997). In developed countries critical care physicians are probably more available to assist outside the ICU should a patient decompensate in the labour ward. In developing countries such as South Africa there are not enough resources for the intensivists to assist in the management of critically ill patients outside the ICU. This is due to larger patient to doctor ratios. Another particular problem is that many South African intensivists and anaesthetists have emmigrated to developed countries such as Australia and the United Kingdom. This migration of highly skilled personnel further compounds the critical shortage of specialist care (Mathiva, 2002).

When managing antenatal obstetric patients it is important to stabilise the mother and ensure adequate oxygen delivery to the fetus (Garite, 2010). A recent systematic review examined foetal outcomes in obstetric cases admitted to general ICU's. Eighteen studies were included in the analysis, in which there were 640 perinatal losses from 2499 obstetric admissions to ICU. The overall perinatal mortality rate was 25.6%. Individual mortality rates ranged from 1.3% to as high as 48.8% (Ananth & Smulian, 2010). While priority is understandably given to the critically ill mother who requires different resuscitation targets to non-pregnant women, the foetal considerations must be taken into account as soon as practically possible. Failure to do so results in high perinatal mortality rates (Garite, 2010). In the context of the obstetric patient in a general ICU, the obstetrician must be integrated into the multidisciplinary team in order to improve maternal and foetal outcomes.

2.5.2 Obstetric admissions to dedicated critical care units in labour wards including described intensive care, high dependency care and intermediate care units

In certain ways, South Africa may proudly lay claim to the origin of critical care in obstetrics beginning in 1978. Van Geldren described a 10 month experience in what he termed a South African obstetric ICU (1978). In the same year Young et al., reported their three year experience of patients admitted to an obstetric ICU (1978). Pregnant and post-partum patient pose specific challenges in terms of altered physiology, foetal monitoring and maintaining a foetal-friendly environment (Garite, 2010; Price et al., 2008). Pregnant patients admitted to an ICU have a greater chance for caesarean section and are especially susceptible to nosocomial infection with drug resistant organisms (ACOG, 2009). In an OCCU midwives are also trained to observe neonates and can assist mothers with breast feeding. It is therefore possible for a mother in a stable condition to keep her baby with her. Due to these reasons there is probably an advantage in managing obstetric patients in a specialised OCCU in the labour ward as opposed to management in a general ICU. There are certain disadvantages to delivery in a general ICU such as a lack of space to conduct a vaginal delivery, accommodate pediatric personnel with their equipment. Other disadvantages include the lack of familiarity of intensivists and critical care nurses with the management of obstetric and neonatal complications.

An OCCU system provides the ideal facility for optimizing both maternal and foetal outcomes in obstetric patients (Young et al., 1978). A specific advantage is that it provides for immediate dedicated obstetric emergency care as well as foetal care and monitoring (Price et al., 2008). It is important for an obstetrician to have appropriate knowledge and skill in the management of obstetric emergencies, as well as the initial resuscitation and critical care management (Paxton et al., 2005).

An OCCU in the labour ward can usually provide invasive monitoring as well as medical and nursing staff with additional experience in obstetric critical care. These units often fall short of, or do not aim to provide prolonged mechanical ventilation. However, short-term ventilation is performed if and when required. In a review of obstetric critical care Baskett stated that 0.9-1.7% of obstetric patients received this level of care while 5-11% were transferred to a general ICU. Haemorrhage and hypertensive disorders constituted the most common indications for admission in this review (2008).

These units should reduce the need for maternal ICU transfer, especially in obstetric complications such as haemorrhage and hypertensive disorders requiring a higher level of critical care. It is important to note that even when dedicated obstetric critical care units are available in labour wards, 5-11% of these patients will still need even more advanced care in a general ICU (Baskett, 2008). Thus, the existence of an OCCU does not negate the role of the general ICU entirely. The function of the OCCU is rather to substantially diminish the burden on the general ICU while optimizing obstetric care.

It is important to recognize the enormous contribution that Van Geldren (1978) and Young et al. (1978), made as the pioneers of in the field of obstetric critical care. These two case series published in 1978, are difficult to compare to more recent studies due to the variation in definitions and levels of critical care and will therefore not be discussed further.

The classification of OCCU and levels of care have been discussed in this chapter. Tables 3 and 4 provide details from reported case series of patients admitted to dedicated obstetric critical care units located in the labour wards of their respective hospitals. These two tables indicate levels of care but have been variously referred to by other terms over the years. These terms include Intermediate Care Unit (Zeeman et al., 2003) and High Dependency Unit (Ryan & Hamilton, 2000). The series by Saravanakumar (2008) covered a period of 23 years and a more detailed description of a four year case series during the same time period.

Table 3: Obstetric Critical Care Units (level 3*)

Location & reference	Total deliveries in area	Number of admissions N (%)	Transfers to general ICU	Maternal Deaths+	Death: admission ratio
Tennessee, USA (Mabie & Sibai, 1990)	22 651	200 (1%)	9	7	1:29
Cape Town, South Africa (Johanson et al., 1995)	28 387	258 (1%)	28	7	1:37
Sao Paulo, Brazil SAMM admissions (Amorim et al., 2006)	NS	933	0	22	1:42

**See page 16, +Maternal deaths in either unit, ^Data extracted from abstract – only as original publication in Portugese, ICU = Intensive Care Unit, NS=Not specified, SAMM = Severe Acute Maternal Morbidity*

Table 4: Obstetric Critical Care Units (level 2*)

Location & reference	Total deliveries in area	Number of admissions N (%)	Transfers to general ICU	Maternal deaths
Dublin, Ireland (Ryan & Hamilton, 2000)	12 070	123 (1%)	5	0
Texas, USA (Zeeman et al., 2003)	28 376	483 (2%)	34	1
Dublin, Ireland (Ryan & Hamilton, 2000)	NS	1359	17	0
Birmingham, UK (Saravanakumar et al., 2008)	NS	1359	39	0
Glasgow, UK (Rajagopal et al, 2011) ^	NS	74	4	0

**See page 21, +Data extracted from abstract, ^High dependency care unit, NS = not specified*

The model of an obstetric intensive care unit described by Mabie & Sibai (1990) (Table 3) is challenging to implement in South Africa and developing countries with similar health care limitations. This is predominantly due to the shortage of sub-specialists in maternal foetal medicine specialists and intensivists. The obstetric intermediate care unit model (level 2 OCCU) described by Zeeman et al. (2003), should be viewed as the gold standard for tertiary units in developed countries. In developed countries it is possible to transfer a patient early to the general ICU when intensive care is required. The most common indication for transfer according to Zeeman et al. (2003) is the need for mechanical ventilation. Early transfer to a general ICU for intensivist management may decrease maternal mortality. In the series of Zeeman et al. (2003), only one of 483 admissions died. International recommendations propose that 8% of all acute adult beds in a referral institution be designated as ICU beds. The recommended acceptance rate to ICU is put at 95% with an average bed occupancy rate of 65% (Standards of Intensive Care Document, 1994).

In countries such as South Africa there are only a limited number of ICU beds available (Naidoo et al., 2013). Therefore early transfer to ICU is often not possible. In South African tertiary hospitals the number of ICU beds accounts for only 1% of all acute adult beds (Mathiva, 2002). For this reason the level 2 OCCU model that requires early transfer of patients in need of ventilation or intensive care to a general ICU is also not the ideal model. The functioning model of the OCCU in Cape Town, South Africa described by Johanson et al., in 1995 (Table 3) is more practical to implement in a South African tertiary hospital. In the overview of critical care medicine in South Africa, Mathiva (2002) highlights significant changes in population demographics since 1992, being the year described by Johanson et al. (1995). At that time (1992), there had been a large increase in the population of Cape Town as a result of migration from rural areas and a larger immigrant population. This caused the decreased availability of the already limited ICU resources in the face of an increase of critically ill patients.

Zeeman et al. (2003) described unpublished data from informal surveys that identified a number of obstetric units North America reporting the capacity to upgrade to a higher level of care in the labour ward when required. In a recent UK survey a number of maternities reported that they do have the capacity to provide a high dependency care in the maternity with multidisciplinary input (including anaethetist and intensivists) (Hussain et al., 2011). In both these surveys there were no specific definitions of what they defined as high dependency care or levels of care provided in the maternity units. However, because none of these maternity units published their high dependency care experience they will not be discussed.

In a recent review on the provision of critical care services for the obstetric population Sultan et al. emphasised the importance of reducing the incidence of SAMM and mortality. It was stated that in specific circumstances there may be a role for labour ward High Dependency Care Units. Specialist obstetric units show lower rates of maternal transfer to intensive care units and provide continuity of care before and after labour (Sultan et al., 2013).

In South Africa, obstetric units in tertiary referral hospitals need at least a level 2 OCCU as a minimum standard, with the capacity to upgrade to a level 3 OCCU when there are no general

ICU beds available. However, under these circumstances patients requiring level 3 critical care should still be placed on the general ICU waiting list and be transferred when a general ICU bed becomes available.

Against the background of limited financial and human resources that is sometimes compounded by lack of intent, it is very important that when and where an OCCU is established, prospective studies documenting maternal and perinatal outcomes before and after the establishment of an OCCU must be performed.

2.6 Guidance for the establishment of an Obstetric Critical Care Unit

During this review the author found no detailed guidance describing exactly how to establish a new OCCU. This means that there was no detailed guidance on the specifications for infrastructure, gas pipelines, electricity and other engineering services, as well as no specifications for equipment. In the field of general intensive care the requirements for an ICU are described in more detail. General ICU guidelines do describe the infrastructure, engineering and equipment specifications, human resources and organization of a general ICU (Standard of Intensive Care Document, 1994; Critical Care Society, 1994; DOH, 2007; Task force on guidelines, 1988; HBN note). In the textbook entitled "*Obstetric Critical Care*" edited by Belfort et al. (2010), the chapter author broadly describes (without specific details) the organization of a critical care obstetric unit in terms of staffing, designing and maintenance of the unit (Scott & Foley, 2010). In terms of staffing, nursing aspects of obstetric critical care units are a key resource that must be carefully addressed in order to ensure effective patient management (McMurtry Baird & Troiano, 2010).

In another textbook entitled "*Obstetric High Dependency Care*" a maternal high dependency care unit is described. In this chapter operational policy, admission and discharge criteria, personnel (medical and nursing), protocols, equipment and clinical governance are broadly outlined (Robinson et al., 2010). Although broad outlines are useful for providing general guidance, the author specifically sought more detailed direction. In this regard, Balachandran et al. (2011) described the establishment of a specialised paediatric cardiothoracic ICU in a low-resource setting, in India. This article is more technical and therefore more valuable in the planning stages of a critical care unit (Balachandran et al., 2011).

In South Africa intensive care units in tertiary hospitals are managed by dedicated medical directors (board certified intensivists). Dedicated board certified consultant intensivists and anaesthetists with experience in critical care, as well as residents provide patient care on a continuous basis. The nurse: patient ratio is 1:1. The reality is that even in 2007 there was a shortage of approximately 291 board certified intensivists and at current rates of training it would take 30 years to establish (Naidoo et al., 2013). These guidelines cannot be applied to OCCUs due the lack of resources and board-certified critical care physicians. At Tygerberg Academic Hospital and other South African academic hospitals, patient care is only taken over by the general ICU team once the patient arrives in that ICU. With this in mind, it is easy to understand the pressing need for a dedicated unit in the labour ward, which is the area in which the obstetrics team has to resuscitate and stabilise critically ill patients and support them until they can be transferred to the general ICU for intensive care. However, the South African National Critical Care Policy contains no description or requirements for a dedicated obstetric critical care unit (DOH, 2007).

In the conceptualization and planning of an OCCU, it is important to combine common standards of care applicable to a general ICU and apply them in an obstetric critical care unit. In this regard, an urgent need exists for a detailed blueprint describing the establishment of an OCCU located within a labour ward. This blueprint should provide sufficient detail to be used by head clinicians, nursing managers, builders and clinical engineers. Another integrated essential part is the planning of an education blueprint to train the midwives and doctors who will provide care in the OCCU.

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CHAPTER 3: A PRE-ESTABLISHMENT AUDIT AND BLUEPRINT TO ESTABLISH A FOUR BED OBSTETRIC CRITICAL CARE UNIT IN THE LABOUR WARD OF A TERTIARY ACADEMIC HOSPITAL

3.1 Context

The Western Cape is one of nine provinces in South Africa. In all the provinces there is a Provincial Department of Health that reports to the National Department of Health. The pre-establishment audit for this study was performed in 2005. The population of the Western Cape Province in the year 2007 was estimated at 5 278 585 and there were 96 821 live births in this province during the same year (NCCEMD, 2008). In the Western Cape Province, high risk, state obstetric patients, including patients at risk or with established organ dysfunction are referred to either one of the two tertiary hospitals. These academic hospitals are Tygerberg Academic Hospital (Stellenbosch University) and Groote Schuur Hospital (University of Cape Town). The number of deliveries in the Western Cape Province increased from 223 420 during the 2002-2004 triennium to 240 651 in the 2005-2007 triennium. The Maternal Mortality Ratio (MMR) for the Western Cape in the 2005-2007 triennium was estimated at 67.6/100 000 live births, which was considerably lower than the national MMR of 152/100 000 (NCCEMD, 2008). While a special effort is made every year by the National Committee for Confidential Enquiries into Maternal Deaths (NCCEMD) and assessors of the Western Cape to identify all maternal deaths, including deaths outside healthcare institutions, in order to determine an accurate numerator, the same cannot be said for most other provinces in South Africa. Taking this into consideration the South African MMR was estimated by other sources to be 181-382/100 000 live births during 2005-2007 (Graham & Newel, 2008).

During the 2005-2007 triennium, a large percentage (52.4%) of the reported deaths occurred in either one of the two tertiary hospitals in the Western Cape Province. In this province, the most common primary causes of maternal deaths were: hypertensive disorders, post-partum haemorrhage (PPH), ante-partum haemorrhage (APH), pregnancy related sepsis, underlying medical disorders, non-pregnancy related sepsis such as pneumonia, tuberculosis and complications of AIDS. The NCCEMD also reported on avoidable factors contributing to maternal deaths. In the two Western Cape tertiary hospitals 30.2% of the maternal deaths had avoidable administrative factors such as the unavailability of ICU beds at the time of the emergency in 9.2% of the cases. One group of avoidable medical factors (30.2%) involved the initial substandard emergency management by health workers. Inadequate resuscitation was a factor in 15.7% of these cases (NCCEMD, 2008). During the triennium under discussion, the Groote Schuur Academic Hospital had a dedicated level 2/3 OCCU (levels described in Chapter 2), while at the Tygerberg Academic Hospital, maternal cases needing critical support, had to compete with all other adult surgical or medical emergencies for general ICU beds. During 2005 there were 57 deaths in the Western Cape Province. Looking at Tygerberg Academic Hospital specifically, the data show that there were around 6198 deliveries performed at the institution and 18 maternal deaths were recorded during 2005 (NCCEMD 2008, Kruger TF).

Obstetricians practicing in South African tertiary hospitals are increasingly confronted with critically ill patients. Often, doctors and nurses with limited experience in critical care have to care for these patients in labour wards with limited access to ICU resources (Mathiva, 2002). It has been shown that when general patients with severe illnesses are grouped together in the same area and cared for by experienced medical and nursing staff, patient outcomes improve. This principle can also be applied to the management of critically ill obstetric patients (Mabie & Sibai, 1990; Zeeman et al., 2003; Lapinsky et al., 1997; Scott & Foley 2010). One of the possible solutions to address the institutional avoidable factors, discussed above, was to establish a level 2/3 OCCU in the Tygerberg Academic Hospital (1 September 2005 to 30 November 2005). However, in order to further support this perceived need, it was deemed necessary to perform a prospective audit (pre-establishment audit) of cases over three months. This audit protocol was approved by the local Ethics Committee.

3.2 A prospective pre-establishment audit

All cases in the labour ward were evaluated on a daily basis using inclusion criteria that would qualify patients for admission to an OCCU. Inclusion criteria were pre-defined according to various international and national Critical Care guidelines described in Tables 1 and 2 as well as Chapter 2. The audit inclusion criteria reflected the proposed OCCU admission criteria stated as: any patient with significant organ system dysfunction or single organ failure including patients with SAMM (Mantel, 1998) criteria. General ICU admission criteria were stated as: patients requiring intubation and ventilation and/or two organ systems failing (DOH policy 67, 2007). The required pre-establishment audit parameters are listed in Table 1.

Table 1: Summary of pre-establishment audit data parameters

Audit data parameters
Patients with OCCU admission criteria
Patients with SAMM criteria
Indication for admission to general intensive care unit
No general ICU bed available
Maternal deaths in the labour ward
Maternal deaths in other wards including general ICU
Advanced monitoring indicated but not received in labour ward: *SaO2 monitoring* *Automated continuous blood pressure* *Intra-arterial blood pressure* *Electrocardiogram (ECG)* *Central venous pressure* *Pulmonary artery catheter*
Respiratory support indicated but not received: *CPAP* *Non-invasive ventilation* *Intubation and ventilation*
Circulatory support required but not received: *Intravenous infusion of antihypertensive agent(s)* *Intravenous infusion of nitrates* *Inotropic support*
Primary causes for morbidity in audited patients: *Hypertensive disorders* *Ante-partum haemorrhage* *Post-partum haemorrhage* *Pregnancy related sepsis* *Non-pregnancy related sepsis* *Underlying medical condition* *Other*

OCCU = Obstetrics Critical Care Unit; SAMM = Severe Acute Maternal Morbidity (Mantel, 1998); ICU = Intensive Care Unit; CPAP = Continuous Positive Airway Pressure

Table 2: Level 2/3 OCCU admission indications

Existing or impending organ failure
Indication for invasive monitoring
Indication for respiratory support
Severe Acute Maternal Morbidity criteria met
General intensive care bed indicated but not available
Complicated pre-eclampsia
Haemorrhagic shock
Acute renal failure
Severe sepsis and/or septic shock
Pre-existing cardiac disorders with significant dysfunction
Medical emergencies such as diabetic keto-acidosis
Morbid obesity
Anaesthetic complications

Detailed admission criteria are given in Appendix 1

The pre-establishment audit was carried out from 1 September 2005 to 30 November 2005. During this three month period, there were 1804 deliveries and sixty three women were found to meet the admission criteria for critical care management in a level 2/3 OCCU. At that time some of these patients had an indication for admission to general intensive care but could not be transferred due to the limited availability of critical care beds in both academic hospitals of the Western Cape Province. These specific patients then had to be managed in the labour ward without the necessary infrastructure, equipment or medical staff with appropriate critical care skills. Unfortunately seven of these mothers died within the labour ward while another two, who were later transferred to the general ICU, also demised (Langenegger et al., 2011). This audit clearly demonstrated the need to urgently establish a level 2/3 OCCU within the confines of the labour ward. Information derived from the audit was also used to predict: the number of admissions to the future OCCU, the expected disease profile, as well as interventions and management required.

An OCCU located within the labour ward can provide the necessary infrastructure, equipment, monitoring, staffing, education and training to effectively manage critically ill patients (Scot & Foley 2010; Zeeman et al., 2003; Johanson et al., 1995). However, specific guidance on how to establish an OCCU is limited (Scot & Foley 2010). In addition, there is still no description or guidelines for an obstetric critical care unit in the South African Critical Care Policy Circular (DOH policies 68, 2007). The following section will detail the blueprint that was constructed and implemented during the establishment of the level 2/3 OCCU at the Tygerberg Academic Hospital.

3.3 Aims and objectives

To compile a detailed blueprint describing how to establish a level 2/3 OCCU within the labour ward of an academic hospital in a developing country.

3.4 Methods

The OCCU must be able to provide appropriate infrastructure and medical care in order to deliver the following clinical and obstetric services:

- Early identification and correct assessment of patients at risk of organ dysfunction, SAMM, established organ dysfunction or failure.
- A resuscitation area for obstetric patients.
- Monitoring of the patient and foetus in a critical care environment.
- Systemic maternal evaluation with appropriate management of the underlying condition.
- Foetal evaluation.
- Management of maternal complications such as: antepartum haemorrhage, postpartum haemorrhage, sepsis, complications of hypertension, respiratory distress, medical complications and post-operative care for patients with or at risk of morbidity.
- The ability to offer short term ventilation and full intensive care prior to transfer to a general ICU or if no such bed is available.

The process began with a review of the literature to provide guidance on design, engineering and clinical standards for an OCCU in a labour ward. The following sources were searched: Medline, SCOPUS, Critical Care Medicine publications, Current Opinion in Critical Care, Critical Care Obstetrics, National Policies on Admission Guidelines for Critical Care and High Care Units from South Africa, Critical Care Society Guidelines from Australia, the United Kingdom, the United States of America and South Africa.

During the planning process consultation occurred with the following key-role players: the Head of the Surgical ICU, an experienced Surgical ICU technician, an architect from the local health department, the renovation and building department of Tygerberg Academic Hospital and clinical engineers. Prof J Anthony, as Head of the only functional OCCU in South Africa at the time, was also consulted together with the Clinical Nursing Manager of his unit, Ms J Frankish.

The OCCU must be able to provide the required infrastructure and medical care to address the following clinical and obstetric services: early identification and correct assessment of patients at risk of organ dysfunction, SAMM and/or established organ dysfunction/failure; resuscitation area for obstetric patients; monitor the patient and foetus in a critical care environment; systemic maternal evaluation and foetal evaluation appropriate management of underlying condition or pathology; manage maternal complications such as: APH, PPH, sepsis, complications of hypertension and medical condition; post-operative care for patients with or at risk of morbidity; ability to function as an emergency area where short term ventilation and intensive care can be provided prior to transfer to ICU or if there are no available ICU beds.

The specific OCCU infrastructure, human resources, equipment, to establish a unit will now be described.

3.5 Unit design

3.5.1 Site

The blueprint located the OCCU in the labour ward in close proximity to the admissions area, obstetric theatres, neonatal resuscitation station and postoperative recovery room. As far as possible, care was taken to provide easy access to the general and neonatal intensive care units. The location of this OCCU in the labour ward allowed access to existing infrastructure such as gas pipelines, emergency power supply and ventilation shafts, which were extended to the OCCU site (Figure 1).

3.5.2 Size and infrastructure construction

In the index study the optimum size in terms of the unit was set at four beds in an open area. The open floor area was set at $80m^2$ in order to allow for at least $20m^2$ floor area for each bed as well as 2.5 meters of unobstructed corridor space between the beds (DOH policy 68, 2007; Intensive Care Society, 1997). In the labour ward of Tygerberg Academic Hospital there was initially no area large enough to accommodate the required OCCU size. In order to create sufficient space the separating wall between a delivery room and an adjacent office was removed (Photo 1). Critical care units with less than four beds pose clinical management challenges in terms of staffing ratios and may not be cost-effective due to scales of economy. Units larger than eight beds on the other hand present problems with regards to unit management (Intensive Care Society, 1997). The doorways of the identified area were wide enough to allow easy passage for a bed and movable equipment (Photo 2). Clinical aspects of addressing adequate size in terms of the number of beds needed was based on general intensive care guidelines. An OCCU should ideally have the capacity to accept 95% of all patient referrals with an indication for admission (Intensive Care Society, 1997).

Figure 1: Floor plan of the Tygerberg Academic Hospital OCCU

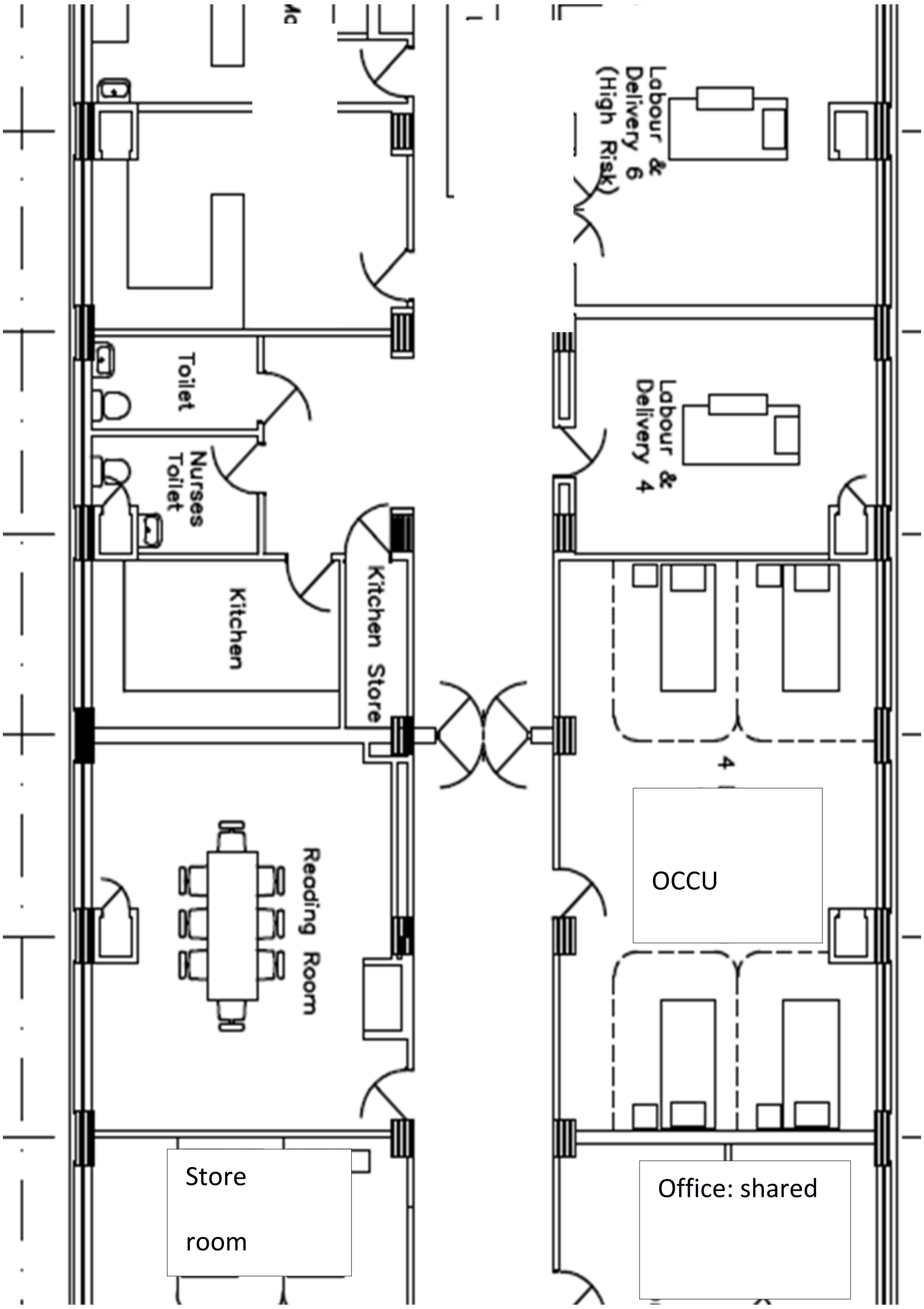


Photo 1: Construction of the Obstetric Critical Care Unit

3.5.3 Bedside layout

At the Tygerberg Academic Hospital OCCU the bed head-to-wall layout was chosen (Photo 2). The unit was furnished with four critical care beds with bedside rails and adjustable height as well as positions (head up, head down, elevate or lower bed). It is useful but not essential to have access to a delivery bed in the event of vaginal delivery, however the majority of deliveries were safely performed on the ICU bed. Delivery beds are more expensive. The available labour ward delivery beds did not have bedside railings and could only be used for a vaginal delivery when the patient was stable and fully conscious with no risk of falling off the bed. There was suitable screening between each bed in the form of material curtains hung from ceiling suspended curtain railings. The walls were strong enough to support equipment fixed from them such as monitors. A rail with a load capacity of 20kg was mounted to the wall for equipment (HBN 27, 1992). The monitors were fixed to the wall using monitor mountings (Photo 3). Adjustable examination lights were suspended from the ceiling. A mobile light was also available. Sufficient lighting is essential to conduct a vaginal delivery or a clinical procedure such as inserting a central venous catheter. Storage as well as a bedside light was available next to each patient's bed (HBN, 1992). Every bed had a mobile trolley with adjustable height for meals, patient files and observation charts. The key requirement for the layout of the bed area was that it had to provide for easy access to the patients. Infrastructure and equipment were mounted in such a way that it did not impede basic nursing care (Intensive Care Society (UK), 1997) (Photo 3).

Photo 2: Permanent infrastructure fixtures and wall bedside layout

Photo 3: Bedside layout

Adequate cupboard space for consumables was available in the unit as shown in Photo 4. Spare equipment and consumables, linen and additional sterile packs were stored in the labour ward store room in a dedicated storage area for OCCU (Figure 1). Other equipment and items stored in the unit cupboards are listed in Table 3.

Photo 4: Cupboard space

Table 3: Essential items in the Obstetric Critical Care Unit cupboard space

Circulation: (infusion lines, intra arterial-lines, central venous catheters, pulmonary artery catheter)
Airway: (oxygen mask, ambu bag, ventilator circuits and filters)
Breathing: (additional oxygen cylinder)
Cables for monitors
Fridge: blood and necessary drugs for cold storage
Other drugs in glass cabinet
Scheduled drugs (e.g. opioids) in a lockable cabinet
Bloodgas analyser on cupboard surface
Environment: gloves, masks, soap, sterile swabs
Disposables
Small capital items (e.g. opthalmoscope, reflex hammer)

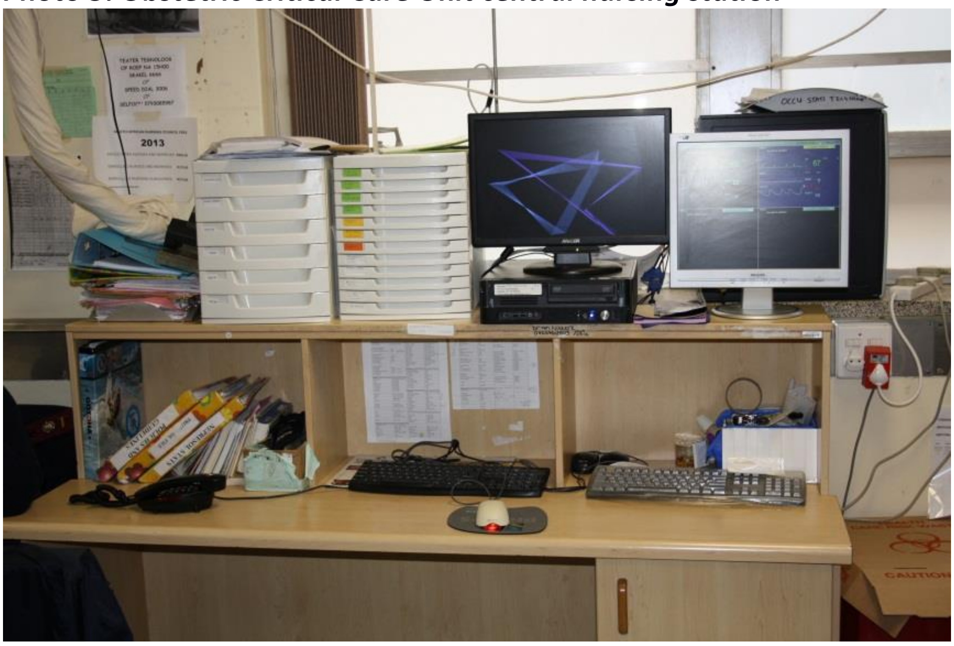
3.5.4 Central nursing station

The central nursing station was sited where direct visual contact with all four patients and their monitors was possible, and close enough to patients to enable the staff to hear any alarms (Photo 5). Storage shelves behind the nursing station desk were necessary to store management booklets, files, forms (e.g. laboratory and blood bank forms) and stationary.

The following nursing station communication facilities were regarded as essential:

- a computer terminal connected to the hospital intranet service,
- an internet link to laboratories and radiology, and
- two telephone extensions; one internal and one external (DOH policy 68, 2007; Balachandran 2011).

Photo 5: Obstetric Critical Care Unit central nursing station



3.5.5 Accommodation

Accommodation such as rooms for dirty linen and tearoom were incorporated into the existing labour ward accommodation where possible in order to save on cost and decrease construction time. It was however important to have a separate office for the nursing manager. The essential accommodation that could be shared with the existing labour ward is listed in Table 4.

Table 4: Accommodation shared with existing labour ward

Reception area
Patient areas
Staff tearoom
Lavatories, showers and cloakrooms
Kitchen facilities
Storage area for case notes
Secretary's office
Doctors sleeping room
Linen rooms
Dirty utility rooms
Clinical waste disposal holding area

3.5.6 Bedside layout of engineering services and specifications

Gas outlets and electric sockets were arranged on the bedside head wall and were easily accessible to personnel (Photo 2). The following infrastructure was essential in order to provide critical care support and specifications were followed to provide adequate oxygen delivery, vacuum and electricity. Recommendations of the European Society of Critical Care Medicine, United Kingdom Health Building Note 27, and the South African Policy on Defining Critical Care were followed to compile a blueprint for bedside engineering services as follows.

Oxygen pipelines

- One socket per bed mounted on the bedside head wall. A supply of 100% medical oxygen was available at a pressure of 4 bar (60 psi, 400 kPa). This pressure was maintained when the flow was 20l/min at each outlet when all outlets in the unit were in use. Emergency oxygen cylinders were available in the unit in case of an oxygen supply problem.

Vacuum

- Vacuum is essential for suctioning patients during intubation, suctioning of endotracheal tube and negative wound pressure suction dressings.
- The OCCU vacuum lines were linked to the central medical vacuum supply. In the OCCU one vacuum outlet was provided for each bed, generating a negative pressure of 50 kPa whilst maintaining 40l/min airflow.

Medical gas (compressed air)

- Optional (**not essential)**
- Medical air outlets in the OCCU were required for older ventilators.
- Many modern ventilators have internal gas mixers and require only an oxygen supply.

Entonox (N_2O 50%: O_2 50%)

- A mobile cylinder with a mask was available. This is however not essential as the ideal method of analgesia in an OCCU is an epidural block.

Electricity

- At least six sockets per bed were required. The power supply had to be 220V single phase, with a single common earth ground and with all outlets in the patient areas on the same phase. Supply lines were not to cause interference with electronic equipment such as monitors or computers.
- The OCCU had to be served by a well-maintained emergency power source with the highest priority rating (to trip in at 185V). This formed part of the hospital emergency power supply and plugs and sockets were coloured red.

Water and basins

- The OCCU required two basins with both hot water and cold water.
- Elbow taps were essential for infection control.
- An adapter can allow for connection of dialysis portable machine.

Ventilation of the unit area

The OCCU was fully air-conditioned. The four bed patient area required at least three air changes per hour via the local air duct ventilation system. Air movement should always be from clean to dirty areas (DOH (SA) policy 68, 2007; DOH (UK), 1992).

Infection control

Infection control measures and their requirements are described in Table 5 below (Balachandran, 2011; DOH policy 68, 2007).

Table 5: Infection control requirements

Antibiotic policy guided by the Department of Microbiology
Infection control guidance on clothing of staff and visitors
Guidance on hand washing methods
Sterilisation of equipment
Aseptic precautions for invasive procedures such as placement of a central venous catheter
Disposable items
Changing of catheters, humidifiers, ventilator filters, tubing and other equipment
Isolation of patients with an infective disease
Barrier nursing
Temparature control

Heating and lighting

The temperature of patient areas was set at 21°C (21-26°C). While natural daylight is best for both patients and staff, good spotlighting is essential for performing procedures and deliveries.

Security and safety

Security and fire safety formed part of the existing labour ward and hospital security plan. Staff had to be informed of plans should there be a security issue or a fire. Expensive movable items were locked and secured.

3.5.7 Equipment

The correct equipment is essential to provide an appropriate level of critical care. Patient physiological variables need to be monitored. Effective respiratory and haemodynamic support equipment are key functions in critical care and may be life-saving. The monitor screens in the unit have to be clearly visible to the medical and nursing personnel. Detailed standards for critical care unit equipment are listed in Tables 6 & 7 and Appendix 2 (Intensive Care Society UK, 1997; Ferdinande, 1997; Scot & Foley 2010; Balachandran 2011).

Table 6: Equipment needed in an Obstetric Critical Care Unit

Large capital items	**Indication**
Resuscitation trolley ***Adult & neonatal***	Maternal resuscitation Neonatal resuscitation Elective and emergency intubation
Defibrillator	Resuscitation
Monitors	Monitor vitals: blood pressure, SaO_2, ECG, respiration, cardiac output
Respiratory support equipment	Bi-PAP*/ CPAP^ machine, Ventilator
Circulatory support equipment	Volumetric infusion pumps Syringe drivers for IV drug infusions
Electric warming blanket	Maintain adequate temperature during critical illness or resuscitation
Small fridge	Drug storage for specific drugs such as suxamethonium Emergency blood products
Cardio-tocograph (CTG)	Monitor foetal heart and contractions
Blood gas analyser (preferable)	Frequent blood gas analysis
Lockable cupboard	Morphine and other scheduled drugs
Procedure trolley	Insertion of arterial lines, central venous pressure catheters (CVP)
Sterile procedure pack	CVP's, arterial lines, epidural
Sterile delivery pack	Delivery of baby
Ultrasound machine	Foetal ultrasound and ultrasound guided procedures, non-invasive CVP

CPAP^= continuous positive airway pressure; Bi-PAP= Bi level positive airway pressure*

Table 7: Other smaller capital items necessary in an Obstetric Critical Care Unit

Durable items	**Non-durable items**
Diagnostic ophthalmoscope	Pressure bags for arterial lines
Wright's spirometer	Normal and large sized blood pressure cuffs
Low temperature thermometer	Pressure air mattress
Oxygen bed rack for transport of patients on a ventilator	Nasal CPAP^ mask sets Full face mask CPAP sets
Fiberoptic laryngoscope & blades	Ambu bags (manual resuscitators)

CPAP^= continuous positive airway pressure

The construction of the unit and purchasing of equipment was performed as a parallel process. The admission guidelines, unit management model, recruiting and allocation of required human resources are described in the following section.

3.6 Admission and discharge guidelines

It was important to decide on appropriate admission guidelines in order to ensure that the resources were used appropriately. The medical and nursing staff as well as infrastructure needed to be planned carefully in order to provide effective care needed by patients admitted to the OCCU. The detailed admission criteria are described in Appendix 1 and the summary of the guidelines is described in Table 2 (page 5).

3.7 Human resources and operational recommendations

In the index study the OCCU level 2/3 human resource management plan was based on a hybrid of the closed general ICU system. (ACOG 2009, Intensive Care Society 1997).

This required the appointment of an obstetrician with an interest in critical care, and the ability to lead and manage the process of establishing the OCCU. In South Africa there are still no specific requirements for the head (director) of an OCCU. In this case the OCCU head met the following requirements: a specialist obstetrician with an interest in high risk obstetrics and a prior three month rotation in a general ICU. Strong support existed within the Department of Obstetrics and Gynaecology and Anaesthetics as well as hospital management. Additional support from Cardiology, Nephrology, the medical and the surgical ICU's was mobilized by the identified head of the OCCU. The duties of the head of the unit are listed in Table 8.

Table 8: Duties and responsibilities of the head of the Obstetric Critical Care Unit

Manage the unit establishment process
Function as multidisciplinary team leader
Establish and monitor admission and discharge criteria
Establish policies and protocols
Quality assurance
Coordinate education and if possible research
Manage the unit budget
Manage staff requirements

After identification of the clinical head, the next important step was to appoint a suitable, dedicated nursing manager for the OCCU. The recommended requirements for the nursing manager are knowledge and skill in critical care and obstetrics. Together, the clinical head and nursing manager proceeded with communicating the vision and care benefits for complicated cases previously managed in a labour ward but now in an OCCU. The nursing manager was responsible for the nursing program including delegation of roles and responsibilities of the nursing staff. Other functions performed by her were the implementation of policies and procedures, quality assurance, provision of supplies and equipment and staff education and training. The above sub-section refers to recommendations while in the study the only additional appointments made were a nursing unit manager and two additional midwife posts (see page 83).

3.8 Day to day care in the Obstetric Critical Care Unit

During the establishment period of the OCCU, daily care was provided by the clinical head, a dedicated registrar (resident) and a dedicated medical officer. Although the OCCU was managed by the clinical head, this person also had other clinical responsibilities. For this reason, additional consultant cover during both office- and after-hours was provided by colleagues on call. The obstetric registrars (residents) or a dedicated senior medical officer provided daytime clinical patient management. The gynaecology registrar on call covered the unit after hours in addition to his general gynaecology commitments. The anaesthetist registrar on call for labour ward was available for pre-operative assessment, critical care advice and when available, to assist with procedures such as intubation and ventilation. The later appointment of a permanent senior medical officer (after the study period), greatly assisted the running and patient management as well as the administration of the OCCU. The duties of the doctors working in the unit are listed in Table 9.

Table 9: Clinical duties of the doctor working in the Obstetric Critical Care Unit

Resuscitation of unstable patients
Assess labour ward patient referrals
Admit patients with, or at risk of organ dysfunction or failure
Do a systematic evaluation
Discuss admissions with the on call consultant
Consult relevant disciplines
Treat the underlying cause
Administrative duties

3.9 Professional nurses

The nurse functioning in the critical care environment should monitor patients closely, make decisions based on that clinical and monitoring assessment, and act accordingly (McMurphy Baird & Troiano, 2010). Midwives and professional nurses working in an OCCU, must be trained in and understand basic obstetric critical care principles as well as midwivery. The nursing staff required for the four bedded unit were, one unit nursing manager, ten professional nurses and five enrolled nursing assistants. The planned work pattern was a 12-hour shift in order to provide two nurses in the OCCU on each shift. Ideally an experienced midwife with critical care knowledge and one general nurse with experience in critical care were placed together on a shift. The duties of the professional nurse and midwife are listed in Table 10. Ancillary nursing staff play a very important role in the OCCU patient management through supporting the professional nurse in her duties under supervision. However they are not able to replace a trained professional nurse and midwife (in South Africa this is one person).

Table 10: Duties of the professional bedside nurse and midwife

Provide compassionate and holistic care
Collect and interpret vital data
Repeated clinical assessments
Communicate relevant findings to the doctor
Interact with family members
Provide patient health care education

Other ancillary staff must be available for consultation when necessary. These include physiotherapists, social workers, nutritionists, radiographers, clinical engineers and critical care technicians when available. The daily program of the OCCU is shown in Table 11.

Table 11: Day to day care in Obstetric Critical Care Unit

Prior to the consultant morning round:

- Nursing staff to assess all vitals
- Collect appropriate blood samples
- Nurse night shift handover to day shift
- Handover by doctor on night shift to day shift doctor
- Systematic re-evaluation by the day shift doctor

At the consultant morning ward round:

- Present clinical information
- Formulate management plan
- Discuss and assess new referrals for admission

Afternoon consultant ward round:

- Update clinical information
- Re-evaluate treatment strategy
- Assess new admissions
- Formulate management plan for night shift

After hours care:

- Nursing handover round
- Doctor handover round
- Assess new referrals
- Discuss new admissions with consultant on call

Photo: Established, fully operational Obstetric Critical Care Unit (2006)

*From left to right: Lenore (midwife & critical care experience), healthy mother and baby (mitral stenosis, pulmonary oedema, antenatal period), Charmaine de Villiers (OCCU nursing manager and critical care tutor), Fred Mattheyse (Obstetric Anaethetist), Eduard Langenegger (Head of OCCU) *With patient permission*

3.10 Conclusion

The establishment of an obstetric critical care unit in a limited resource environment is an achievable challenge which requires planning, teamwork and dedication. The discipline of obstetric critical care must be expanded wherever possible. The blueprint described in this chapter can be implemented in tertiary hospitals in both developing and developed countries.

The advantage of identifying a dedicated area for emergency care in labour ward is that the infrastructure in terms of building, washing basins, oxygen and suction lines, emergency power, beds, infusion pumps, access to basic stock, resuscitation trolley is readily available. The human resources is also available but needs to be trained in knowledge and skill. The main capital expense is the purchase and maintenance of monitoring and respiratory support equipment, bloodgas machine.

3.11 References

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3.12 Appendices

Appendix 1: Detailed admission criteria for Obstetric Critical Care Unit

Any obstetric patient with existing, developing or impending organ failure or dysfunction which places the patient at risk of death or long term morbidity

1. Any indication for:
   - Haemodynamic monitoring, invasive or non-invasive ventilatory support, including CPAP and BIPAP.
   - Intravenous haemodynamic therapy such as severe, resistant, hypertension requiring continuous infusion of an antihypertensive agent.

2. Severe acute maternal morbidity marker(s) as defined by Mantel et al., 1998 (See Table 2).

3. Obstetric patients requiring a general intensive care bed; that cannot be transferred due to lack of medical or surgical ICU beds in the metropole of the Western Cape.

4. Hypertensive disease

   Pre-eclampsia with organ dysfunction:
   - Metabolic acidosis
   - Coagulopathy
   - Renal failure, significant renal dysfunction, oliguria not responding to primary management in the labour ward
   - Severe uncontrolled hypertension
   - Eclampsia with encephalopathy
   - Pulmonary oedema
   - Respiratory distress as defined: respiratory rate more than 28 breaths/minute, related to respiratory or cardiovascular pathology.
   - Abruptio placentae with intrauterine fetal death.
   - Hypertensive crisis requiring continuous arterial monitoring in cases of resistant hypertension where continuous intravenous therapy is indicated.

5. Severe haemorrhage
    - Class III -IV Shock (obstetric haemorrhage)
    - Coagulopathy
    - Abruptio placentae with intrauterine fetal death
    - Haemorrhage requiring total abdominal hysterectomy
    - Haemorrhage requiring massive blood transfusion (defined as >5 units blood during resuscitation)

6. Acute renal failure
    - Resistant oliguria
    - Uremic complications

7. Jaundice
    - Acute fatty liver of pregnancy
    - Pre-eclampsia and jaundice

8. Severe sepsis
    - Severe sepsis or septic shock
    - MODS (multi organ dysfunction)
    - Sepsis requiring hysterectomy or laparotomy

9. Cardiac disease
    - Complicated valvular heart disease
    - Cardiomyopathy
    - Cardiac failure or dysfunction

10. Respiratory disease
    - Respiratory failure/distress/respiratory rate >28
    - Pulmonary oedema/pneumonia/severe asthma
    - Adult respiratory distress syndrome (ARDS)
    - Pulmonary embolism – amniotic/thrombotic/other

11. Endocrine emergencies
    - Diabetic complications e.g. diabetic keto-acidosis
    - Thyroid crisis

12. Obesity
    - BMI >50
    - BMI >40 with co-morbidity such as diabetes, hypertension
    - OSA (Obstructive sleep apnoea)

13. CNS emergencies
    - Depressed GCS (Glasgow coma scale)
    - Suspected intracranial haemorrhage, oedema

14. Anaesthetic or intraoperative complications
    - High spinal
    - Hypovolaemic shock
    - Intraoperative cardiac arrest

Patients requiring full ventilation should be managed in a general ICU but the OCCU must have the capacity and skills to resuscitate and perform short term ventilation.

Appendix 2: Equipment specifications

Appendix 2.1

Option 1 – Monitor specifications (Entry level critical care monitor)
• ECG, respiration rate, pulse oximetry, non-invasive blood pressure, temperature, one multi-port capable of receiving two or more transducers for measuring invasive pressures
• 8.4 inch colour screen, 5 or 6 waveform traces, full trending, vital signs listing & arrhythmia detection, mains & battery operative electrode lead, 3 electrodes
• ECG connection cord
• Non-invasive blood-pressure (NIBP) cuff, adult
• Air hose for NIBP
• SpO_2 (saturation) connection cord
• Finger probe, SpO_2
• Temperature connection cord
• Cables for connecting pressure transducers to the monitor
• Rechargeable battery

Appendix 2.2

Option 2 – Monitor specifications to include pulmonary artery catheter monitoring (bedside monitor)
• ECG, Resp, NIBP, SpO_2, 3 Ports for Invasive BP, Temp, CO_2, Cardiac Output monitoring)
• 12.1 inch colour screen, 6 waveform traces, full trending, vital signs listing & arrhythmia detection, Mains & Battery operative electrode lead, 3 electrodes
• ECG connection cord
• NIBP cuff, adult
• Air hose for NIBP, 3.5 metres
• SpO_2 connection cord
• End tidal CO_2 connection cord
• Finger probe, SpO_2, TL-201T
• Cables for connecting pessure transducers to the monitor
• Temperature connection cord

Appendix 3: Respiratory support equipment

Appendix 3.1

Non-invasive respiratory support
• BiPAP and CPAP system for non-invasive breathing support
• Must need only an oxygen wall gas port (internal gas mixer)

Appendix 3.2

Specifications for an intensive care ventilator
• Consider auto intelligent ventilators with Adaptive Support Ventilation
• Ventilator (internal air mixer, only O_2 pipeline or bottle needed) with standard accessories, including colour, graphics, Auto, backup battery, mobile cart with circuit arm, oxygen
• Ventilator adult/paediatric including full leak tolerant /compensation non-invasive mode. – Including Colour & Graphics Options, Auto Track, and Backup battery
• O_2 hose, flex arm, flex arm bracket, single reusable expiratory, Colour, Graphics, Trending, Trolley, O_2 Sensor, 1 Reusable Circuit, Test Lung and Support Arm

Appendix 4: Defibrillator

Option 1(preferred)
• Biphasic Defibrillator, built-in printer and Colour ECG monitor
• Adult & paediatric paddles. These may have been the original intention, but today we use electrodes that are attached to the skin
• Synchronized Cardio version
• Mains & battery operative accessory kit, includes: 3-lead ECG cable, power cable, 1 x tube defibrillator gel
• Rechargeable battery
Option 2
• # Automated defibrillator devices (cheaper)

CHAPTER 4: A PROSPECTIVE COMPARISON OF PATIENT OUTCOMES BEFORE AND AFTER THE ESTABLISHMENT OF AN OBSTETRIC CRITICAL CARE UNIT IN SOUTH AFRICA

4.1 Context of the study

The maternal mortality rate in South Africa during 2005-2007 was officially reported as 152 (Saving Mothers, 2008) but other estimates placed it as high as 181-382/100,000 deliveries (Graham & Newell, 2008). In comparison the maternal mortality rate in the UK was only 11.4/100,000 during 2006-2008 (CMACE, 2011). Of the avoidable factors identified for tertiary hospitals in the South African Saving Mothers report, 30.1% were related to clinical management while 9.2% were related to lack of ICU and critical care facilities (Saving Mothers, 2008). In 2007 the population of the Western Cape province of South Africa was 5,278,585. This represented a 16.7% increase from 2001. This province is one of the main destinations of migrants from other provinces. During 2007 there were 96,821 deliveries within the province, while 187 maternal deaths were recorded during the 2005-2007 period with a calculated maternal mortality rate of 67.6 deaths / 100 000 deliveries (Saving Mothers 2010). There are only two tertiary hospitals (Tygerberg and Groote Schuur) serving the Western Cape population. At Tygerberg Academic Hospital there was an increase in the number of deliveries including patients admitted with severe acute maternal morbidity (SAMM) and/or organ dysfunction. At the time of the study, 14 general ICU beds available at Tygerberg Academic Hospital. This figure is far below the recommended number of beds per population served (see Chapter 3). The labour ward in the hospital did not have the infrastructure, equipment or appropriately trained staff to manage critically ill patients. Due to limited capacity, these patients were often only admitted to the Tygerberg Academic Hospital general ICU if they deteriorated further, in other words, late in the courses of their illnesses. These factors resulted in an increase in the institutional maternal mortality. During 2005, 18 maternal deaths occurred at Tygerberg Academic Hospital.

Basic and Comprehensive Emergency management of Obstetric Care (CEmOC) is a critical component of obstetric care used to reduce maternal morbidity and mortality. (Paxton et al., 2005; CMACE, 2011). However, frequently obstetric patients that present with SAMM and/or developing or existing organ dysfunction or failure are at risk of dying (Mantel, 1998). The provision of EmOC which includes basic interventions such as hand washing, administration of antibiotics, administration of magnesium sulphate and the more advanced CEmOC which includes the availability of caesarean section and blood transfusion will not decrease morbidity and mortality in this group of patients (Theron, 2012). Patients with organ-dysfunction require early recognition, early initiation of resuscitation and critical care management. This can be facilitated by transferring the sickest patients to a dedicated area in the labour ward which has the necessary infrastructure, equipment and skilled medical and nursing staff (Scott & Foley, 2010). There was several case series described in the literature illustrating improved outcomes for obstetric patients when they are managed in OCCU's (Mabie & Sibai, 1990; Johanson et al., 1995; Zeeman et al., 2003). Due to the critical nature of the conditions affecting these obstetric cases, randomised trials are not found in the literature. In addition, no studies describing the situation before and after the establishment of a level 2/3 OCCU was found. Against the background of a relatively high MMR, together with the will and capacity to address the challenge it became a high priority to establish an OCCU in the labour ward of Tygerberg Academic Hospital during 2006 with the goal of this intervention to decrease maternal mortality and morbidity. It was therefore deemed necessary to study the impact of the establishment of this level 2/3 OCCU. A prospective audit performed before and after the establishment of this unit was carried out and will now be described.

4.2 Hypothesis

Through the establishment and efficient use of an OCCU the maternal mortality and morbidity in critically ill obstetric patients can be decreased.

4.3 Objective

To demonstrate improved outcomes in critically ill obstetric patients with existing or developing organ dysfunction, when managed in a dedicated level 2/3 OCCU according to critical care management principles at Tygerberg Academic Hospital.

4.4 Methods

The study was performed in the labour ward at Tygerberg Academic Hospital. This hospital serves as both a secondary (referral for specialist care) and a tertiary (referral for subspecialist care) referral unit. Tygerberg and Groote Schuur Hospitals are the only tertiary hospitals for adults in the Western Cape Province of South Africa. The number of deliveries performed in the entire Tygerberg Academic Hospital referral region during 2005 was 35 506, 67% of these deliveries occurred in the Metro (personal communication G Gebhardt, situational analysis WC), while the number of deliveries performed in Tygerberg Academic Hospital during the same year was 7,489. The study population was comprised mainly of women of mixed race or African Origin and also mostly of low socio-economic status. No formal sample size calculation was performed in the study due to the following reasons. In his literature review the author found no reliable before- and after studies dealing with obstetric critical care units. There is robust evidence to support the hypothesis that critical care facilities are efficacious in saving lives. Mortalities are concentrated in tertiary referral units and therefore differences following a definitive change in management are more quickly demonstrated. A strategic decision by the Provincial Administration had been taken to implement the establishment of an OCCU in Tygerberg Academic Hospital in order to reduce maternal mortality in line with national and international objectives. With this operational and moral imperative in mind, the advice of the local statisticians was to implement the described three-month audit periods.

A prospective audit of patients in the labour ward who would have qualified for critical care management according to specific criteria was carried out before the establishment of the Tygerberg level 2/3 OCCU ("Before OCCU" group). Subsequent to the opening of the OCCU, data was collected from all patients admitted to the OCCU during the corresponding time period one year later to control for seasonal variation in disease patterns ("After OCCU" group). The goal was to compare the two sets of data.

A specific audit sheet was designed by the principal investigator with input from both promoters. This audit sheet was completed daily during admission for all patients who met the pre-defined inclusion criteria for admission to a level 2/3 OCCU or general ICU. Outcomes were followed up to 42 days post-delivery by reviewing the patient files. The audit was carried out by the principal investigator on a daily basis. If this person was not available, the audit sheet was then completed by a senior registrar and the file and data sheet were then reviewed later by the principal investigator. While maternal mortality is a hard endpoint, the definitions of morbidities, sub-standard care and avoidable factors were standardised categorically (as far as possible) within the department and according to South African national criteria. This latter categorisation was performed and practiced in order to avoid investigator bias as no independent review was performed in this study.

The work flow pattern in the hospital was as follows. All obstetric patients were transferred to obstetric admission area, where after they were admitted into the labour ward. If found to be critically ill, they were referred to general ICU and/or OCCU in the “After OCCU” group.

All data was collected according to the same methodology. Inclusion criteria for patients requiring care in an OCCU or general ICU were: antenatal, intra-partum and post-partum obstetric patients with impending, developing or established organ dysfunction that could lead to long term morbidity or death. This included any obstetric patients with an indication for transfer to a general ICU and obstetric patients with the following requirements: invasive haemodynamic monitoring, non-invasive respiratory support (continuous positive airway pressure support or non- invasive mask ventilation), emergency invasive ventilation where no general adult ICU bed was available and general ICU step-down care. More detailed indications for obstetric critical care are described in Chapter 3 and in Appendix 1 of Chapter 3. Exclusion criteria were: non-obstetric patients and patients with early pregnancy complications (<20 weeks gestation) such as miscarriage or ectopic pregnancies, (these patients were admitted to the surgical ICU as per hospital policy), as well as death before arrival at TYGERBERG ACADEMIC HOSPITAL and futile care for example, brain death on arrival (DOH (SA), 2007).

Patients in the “Before OCCU” group were managed in the labour ward using standard labour ward infrastructure, equipment and human resources. Patient management was according to the hospitals' routine standard of care. Patients in this group were managed by the on-call obstetric medical team (obstetric consultant, registrar, house officer) and qualified skilled midwives in delivery rooms and postnatal labour ward rooms. Oxygen, nitrous oxide and vacuum suction were available. No ventilators were available in the labour ward and medical and nursing staff did not have additional critical care experience. Neonatal resuscitation equipment, a resuscitation trolley and a defibrillator were available. No advanced monitors

(SaO_2; non-invasive blood pressure, invasive blood pressure, ECG) or other respiratory support equipment were available in the labour ward. Vital observations were recorded by nursing staff manually. No early warning observation chart systems were used. Only two pulse oximeters were available in the labour ward. No official guidelines for the management of critical care emergencies or ICU transfer were available at that time. Critically ill patients requiring intensive care were referred to the general ICU but if no ICU beds were available, patients had to be managed in the general labour ward.

The Tygerberg Academic Hospital OCCU was established in March 2006 and the "After OCCU" group of patients with inclusion criteria was managed in the OCCU. The necessary infrastructure, equipment, appropriate human resources were utilised to manage critically ill obstetric patients according to obstetric critical care principles. Patients were initially admitted to labour ward and then referred to the OCCU where they were stabilised and managed or transferred to the general ICU according to the defined criteria (see page 53). The systematic evaluation of the obstetric patient and an organ-based approach was followed (Lombaard et al., 2005; Price et al., 2008). The OCCU was equipped with four patient monitors which included ports for invasive blood pressure measurement, central venous pressure and pulmonary artery catheters. Respiratory support equipment available included one CPAP machine and a standard ventilator.

The unit was managed by a specialist obstetrician and a nursing manager following the closed unit operational plan (see Chapter 3). The doctors and midwives working in the unit received informal additional in service basic critical care knowledge and skills training. There were clearly defined admission and discharge policies. Specific management protocols were available such as sepsis, acute severe hypertension and renal dysfunction in pre-eclampsia. Obstetric registrars (residents) were responsible for patient management from Monday to Friday during 08:00-16:00 and the unit director provided clinical supervision. The on-call senior gynaecology registrar under supervision of the on-call obstetric specialist was responsible for clinical patient management after hours but certain procedures such as caesarean sections and other necessary major surgery e.g. hysterectomy, were performed by the on-call team in the labour ward. An obstetric critical care management booklet and early warning observation sheets were used. In both the "Before OCCU" and "After OCCU" groups there was anaesthetic assistance for critical care advice or procedures such as epidurals. Inter-disciplinary consultation was available for both groups of patients.

The primary and secondary outcome measures for this leg of the study were as follows:

Primary outcomes:

- Mortality and major morbidity after admission.

Secondary outcomes:

- Appropriate management with regards to monitoring and organ support
- Complications of management
- Duration of admission to OCCU
- Comparison of APACHE Scores in the “Before OCCU” and “After OCCU” groups
- Neonatal outcomes in the “Before OCCU” and “After OCCU” groups

Data were analysed by a statistician from the Statistics Department of Stellenbosch University. Statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS) version 10. Categorical data were analyzed using the Chi-square test, as well as odds ratios with 95% confidence intervals where applicable. Where an expected cell value was less than five, the Fisher exact test was used. Continuous data was analyzed using the Student’s T-test, and for non-parametric data the Mann-Whitney-U test was used. All tests utilized the 5% level of significance.

Ethical permission was obtained from the Ethics Committee of Stellenbosch University (NO7/05/112). Anonymity of data was maintained by assigning a specific number to each patient after data collection.

4.5 Results

Patient data was collected over a three month period from 1 September to 30 November 2005, before the OCCU was established and thereafter from 1 September to 30 November 2006 after the OCCU was established. For the purpose of the following sections the group of patients included before the establishment of the OCCU will be referred to as the “Before OCCU” group and the patients admitted to the OCCU after the establishment of the Unit will be referred to as the “After OCCU” group.

During these audit periods there were 1804 deliveries in the labour ward of Tygerberg Academic Hospital during the "Before OCCU" period and 1727 deliveries in the same institution during the "After OCCU" period. Not all patients qualifying for OCCU in either period were necessarily delivered in Tygerberg Academic Hospital. In the three month "Before OCCU" period, 63 patients (38 antenatal, 25 postnatal) (63/1804 = 3.5%) met criteria for Obstetric Critical Care or general ICU admission. In the "After OCCU" group 60 patients (32 antenatal), 28 postnatal) (60/1727 = 3.5%) were included. There were no significant differences between the two groups in maternal baseline characteristics (Table 1).

Table 1: Maternal baseline characteristics on admission to labour ward or Obstetric Critical Care Unit

	Before OCCU* n = 63	**Median**	**Range**	**After OCCU n = 60**	**Median**	**Range**	**p-value**
Age	63	26	14-43	60	27	15-47	0.61
Gravidity	63	2	1-5	60	2	1-6	0.72
Parity	63	1	0-5	60	1	0-5	0.25
Antenatal^	38 (60,3)			32 (51,2)			0.54
Post natal^	25 (39,7)			28 (48,8)			0.43
HIV +#	14			15			0.35
APACHE score$	63	10	0-42	60	8	3-29	0.89
Gestation at time of event (weeks)	60	35	20-42	60	34	20-42	0.08

**OCCU - Obstetric Critical Care Unit ; ^ n (%)' #Denominator in "Before OCCU" group = 55 and in "After OCCU" group = 47' $APACHE - Acute physiology age chronic health evaluation*

There were no significant differences in the HIV status between the "Before OCCU" and "After OCCU" groups (Table 1), however, there was a significant difference in patients with AIDS. There were five cases of AIDS in the "Before OCCU" and 12 in the "After OCCU" groups (p=0.02). There were no significant differences in the raised BMI categories shown in Table 2.

Table 2: Body mass categories > 40 kg/m^2

BMI	**Before OCCU* n = 31**	**After OCCU n = 33**	**p-value**
>40	10	10	0.91
>45	6	5	0.82
>50	2	0	0.26

**OCCU - Obstetric Critical Care Unit*

There were no significant differences in the organ-based admission criteria as shown in Table 3.

Table 3: Admission indications based on organ system dysfunction

Organ based criteria	Before OCCU*	After OCCU	p-value
Hypertension	38	36	0.97
Haemorrhage	14	9	0.30
Cardiac	11	12	0.72
Pulmonary	26	33	0.13
Renal	20	17	0.68
Metabolic/endocrine	8	14	0.12
Neurological	11	5	0.13
Severe Sepsis#	11	19	0.07
Anaesthetic complication	1	1	0.73
Other	2	0	0.24

Results given as n = number of organ system dysfunctions. Note a patient may have more than one organ system dysfunction.
**OCCU - Obstetric Critical Care Unit #Sepsis and organ dysfunction*

The indications for admissibility (in the "Before OCCU" group) or admission (in the "After OCCU" group) were also divided into direct and indirect obstetric causes of the condition according to the system used in the Saving Mothers Report (Saving Mothers, 2005).

There were 40 direct obstetric causes for admission in both groups (p=0.71) (Figure 1). With regard to the indirect obstetric causes for admission, there were 20 in the "Before OCCU" group and 23 in the "After OCCU" group (p=0.91) (Figure 2).

Figure 1: Direct obstetric causes of admission in respective group

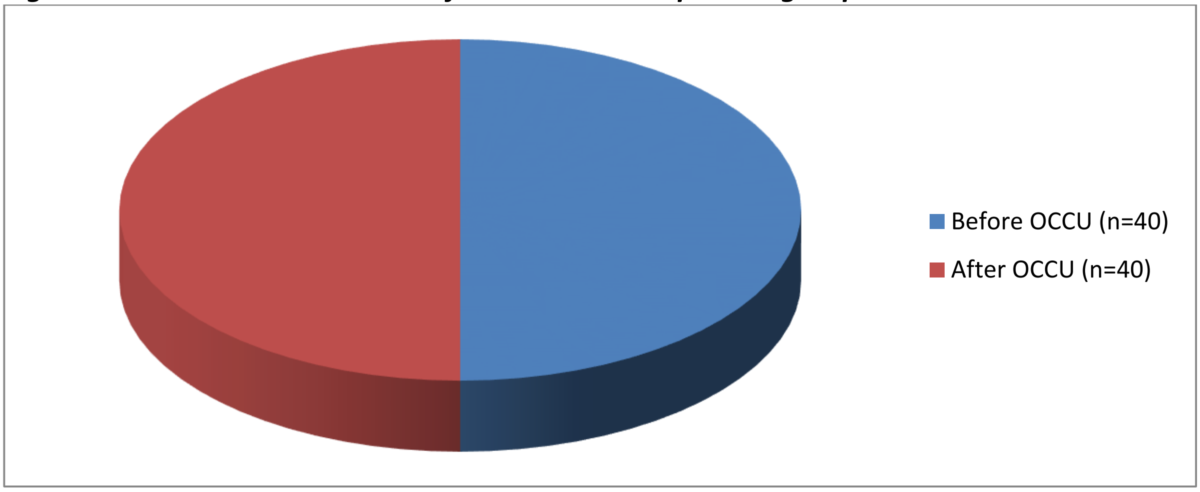
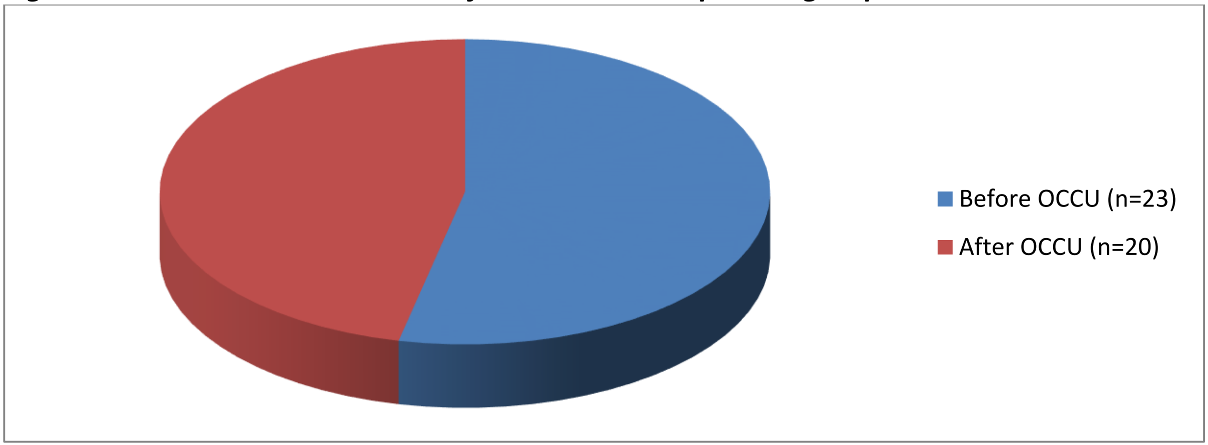


Figure 2: Indirect obstetric causes of admission in respective group



The most important (numerically) direct and indirect obstetric causes of admission are shown in Table 4.

Table 4: Important direct and indirect causes of admission

	Before OCCU*	After OCCU	p-value
Hypertensive disorders in pregnancy	38	36	0.97
Obstetric Haemorrhage	14	9	0.3
Severe pregnancy related sepsis	4	5	0.67
Severe non pregnancy related sepsis	7	14	0.03
Pre-existing cardiac disorders	11	12	0.72

*Results given as n = number of causes, patients may have more than one admission indication; *OCCU - Obstetric Critical Care Unit*

In both groups, complications of pre-eclampsia were the most common causes for admission as shown in Table 5. Respiratory dysfunction, reflecting both obstetric and non-obstetric conditions, was the next most common group of causes as shown in Table 6. Sepsis, again reflecting both obstetric and non-obstetric conditions, was the third most common cause (Table 7). Within the non pregnancy related sepsis category HIV/AIDS was the dominant factor as expanded in Section 4.6.10.

Table 5: Complications of pre-eclampsia

	Before OCCU*	After OCCU	p-value
Severe, resistant hypertension#	30	31	0.65
Pulmonary oedema$	16	14	0.83
Left ventricular failure	4	5	0.65
Renal Injury+	8	8	0.92
Acute renal failure+	7	7	0.9
Complicated eclampsia^	10	9	0.47
Encephalopathy (unrelated to eclampsia)	3	1	0.23
HELLP syndrome$^{\Delta}$	10	16	0.14

Results given as n = number of complications. Patients may have more than one complication
**OCCU - Obstetric Critical Care Unit; #Systolic blood pressure >160mmHg and/or diastolic blood pressure >110mmHg, not responding sufficiently to acute anti-hypertensive management; $Diagnosed clinically and radiologically; +Increase in serum creatinine × 2 and/or urinary output < 0.5 ml/kg/h × 12 hours; Acute renal failure= increase in serum creatinine ×3 and or urinary output < 0.3ml/kg/h × 24 hours or anuria for 12 hours (Gammill & Jeyabalan, 2005) ^Recurrent convulsions and/or encephalopathy; $^{\Delta}$Haemolysis, elevated liver enzymes and low platelets*

Table 6: Respiratory system dysfunction

	Before OCCU*	After OCCU	p-value
Respiratory rate >35bpm# on 40% O_2 face mask	15	23	0.08
Respiratory rate 29-34bpm on O_2 face mask	23	26	0.45
Intubation	14	7	0.13
CPAP$/BiPAP+	1	28	0.00
Tuberculosis	4	10	0.07
Pneumonia	9	19	0.02
Pulmonary oedema	18	16	0.81

Results given as n = number of cases.
**OCCU - Obstetric Critical Care Unit; #breaths per minute; $CPAP - Continuous positive airway pressure; +BiPAP - Bi-level positive airway pressure*

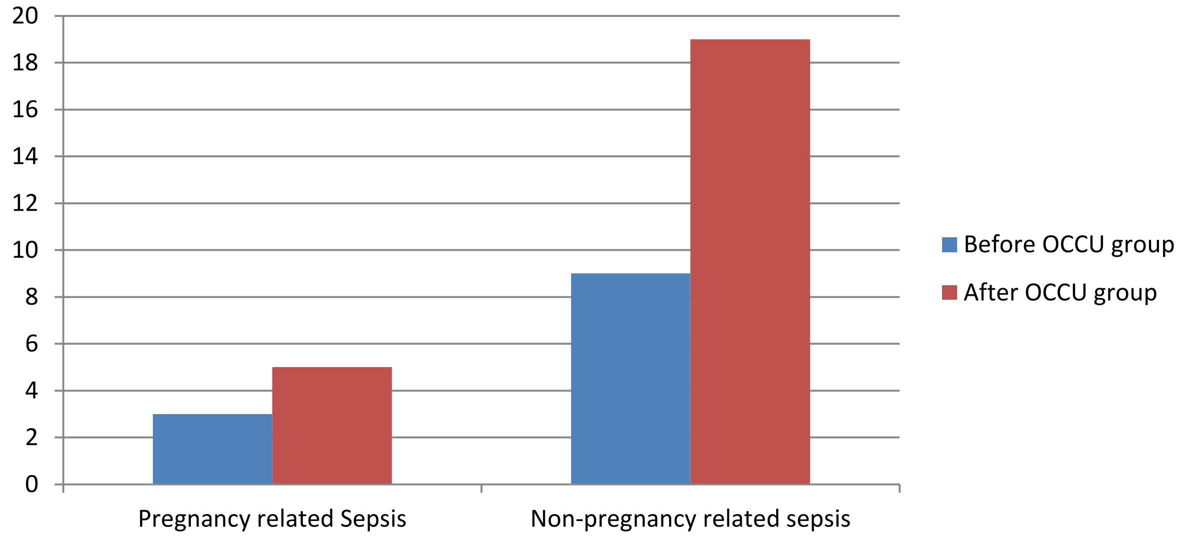
Table 7: Sepsis and multiple organ dysfunction syndrome

	Before OCCU*	After OCCU	p-value
Sepsis	13	23	0.31
Severe sepsis#	11	19	0.07
Septic shock$	3	3	0.95
MODS^	7	6	0.84

Results given as n = number of cases, patients may have more than one category of sepsis
**OCCU - Obstetric Critical Care Unit; #Sepsis and organ dysfunction; $Sepsis and fluid resistant hypotension; ^MODS - Multiple organ dysfunction syndrome*

In the "Before OCCU" and the "After OCCU" groups, non-pregnancy related infections were the most common causes of sepsis ("Before OCCU" group = 9; "After OCCU" group = 19 (p=0.02)). The incidence of pregnancy related sepsis did not significantly differ between the groups; three in the "Before OCCU" group and five in the "After OCCU" group (p=0.42). This is shown graphically in Figure 3.

Figure 3: Pregnancy and non-pregnancy related sepsis



Difference in non-pregnancy related sepsis groups p=0.02

There were no significant differences in SAMM markers on admission between the "Before OCCU" and the "After OCCU" groups as shown in Table 8.

Table 8: Severe acute maternal morbidity on admission

	Before OCCU* n = 63	After OCCU n = 60	p-value
Total SAMM	46	40	0.44
ICU transfer	20	13	0.21
Anaesthetic complication	1	0	0.33
Pulmonary oedema	18	16	0.81
Cardiac arrest	1	0	0.33
Acute renal failure	10	7	0.50
>5u blood transfusion	11	10	0.90
Hysterectomy for haemorrhage	2	4	0.37
Hysterectomy for sepsis	1	2	0.53
Intubation and ventilation	14	7	0.13
Pulmonary embolus	2	0	0.16
Diabetic keto-acidosis	0	2	0.14
Pre-eclampsia and jaundice	0	1	0.30
ICU transfer for sepsis	7	7	0.92
Platelet transfusion	4	8	0.19
Intracranial haemorrhage	0	1	0.30
Coma	4	3	0.44

*Results given as n = number of cases, patients may have more than one category of SAMM; *Obstetric Critical Care Unit; definitions of SAMM as in Table 5.*

Upon completion of the initial dedicated evaluation, which was virtual (in the sense that the OCCU did not yet exist) in the "Before OCCU" group and real in the "After OCCU" group, the management and monitoring required by the specific condition was documented. The performance or "non-performance" of the indicated management and monitoring plans were audited. The outcomes are shown in Tables 9, 10 and 11.

Table 9: Implementation of indicated special monitoring in the labour ward ("Before OCCU") and the "After OCCU" groups

	Before OCCU*	After OCCU	p-value
SaO_2 indicated	56	57	0.22
SaO_2 monitoring received	7	57	0.00
Intra-arterial line (a-line) indicated	57	51	0.35
A-line received	3	47	0.00
Complication	0	2	1.00
Central venous pressure line (CVP) indicated	35	37	0.49
CVP received	10	31	0.00
Complication	1	1	0.48
Pulmonary artery catheter (PA) indicated	11	11	0.93
PA catheter received	1	3	0.27
Complication	0	0	

Results given as n = number of cases, patients may have more than one category of SAMM
**OCCU - Obstetric Critical Care Unit; definitions of SAMM as in Table 5.*

Respiratory support was indicated in both the "Before OCCU" and "After OCCU" groups and the provision of this indicated support was audited. There were significantly more patients with pneumonia in the "After OCCU" group ("Before OCCU" group = 9; "After OCCU" group = 19 (p=0.02)). There was also a significant difference in patients with AIDS, five in the "Before OCCU" group and 12 in the "After OCCU" group (p=0.02). The types of respiratory support management indicated and whether they were received or not, are listed in Table 10.

Table 10: Implementation of respiratory support indicated in the labour ward ("Before OCCU") and the "After OCCU" groups

	Before OCCU*	After OCCU	P-value
CPAP# indicated	30	30	0.79
CPAP received	0	28	0.00
BiPAP$ indicated	5	12	0.05
BiPAP received	0	11	0.00
Invasive ventilation indicated	15	8	0.14
Invasive ventilation received	9	7	0.23

Results given as n = number of cases, patients may have more than one category of respiratory support
OCCU - Obstetric Critical Care Unit; #CPAP - Continuous positive airway pressure; $BiPAP - Bi-level positive airway pressure

Indications for drugs affecting haemodynamics such as intravenous labetalol, hydralazine, inotropes, and nitrates were noted and the performance or "non-performance" of the indicated management was audited as shown in Table 11.

Table 11: Implementation of haemodynamic support indicated in the labour ward ("Before OCCU") and the "After OCCU" groups

	Before OCCU*	After OCCU	p-value
Continuous IV anti-hypertensive infusion indicated	25	26	0.68
IV anti-hypertensive infusion received	2	23	0.00
Inotropic support indicated	10	9	0.89
Inotropic support received	4	9	0.01
IV nitrates indicated	15	13	1.00
IV nitrates received	0	13	0.00

OCCU - Obstetric Critical Care Unit

Three patients in the "Before OCCU" group had an indication for dialysis and duly received this procedure. None of the patients with renal dysfunction or failure in the "After OCCU" group required dialysis (p=0.13).

There were nine maternal deaths in women with SAMM on admission in the "Before OCCU", and two mortalities in the "After OCCU" group (p=0.05 two-tailed Fisher's exact test; p=0.04 one-tailed Fisher's exact test).

The duration of hospital as well as days spent in the labour ward, OCCU and the general ICU are demonstrated in Table 12.

Table 12: Duration stay in hospital area

	N	Median (range)	p-value
Hospital days (before OCCU)*	63	6 (0-36)	
Hospital days (after OCCU)	60	9 (1-42)	<0.01
Labour ward days (before OCCU)#	62	3 (0-14)	
OCCU days (after OCCU)	56	2 (0-6)	0.02
General ICU stay (before OCCU)	20	2 (1-24)	
General ICU stay (after OCCU)	13	3 (1-17)	0.21

[*]Total admission time in the hospital; [#]Days spent in the labour ward by patients with admission criteria for OCCU prior to the establishment of the unit

There were 20 transfers to the general ICU in the "Before OCCU" group and 13 in the "After OCCU" group (p=0.21). The indications for these transfers are listed in Table 13.

Table 13: Indications for transfer to the general ICU

	Before OCCU* n=20	After OCCU n=13	p-value
Cardiovascular#	6	6	0.92
CPAP$	6	0	0.02
Intubation and ventilation	10	7	0.83
Renal failure	5	1	0.20
Neurological+	4	2	0.68
Sepsis	5	4	0.79
Haemorrhagic shock	5	3	0.51

Patients may have more than one indication for transfer
[*]OCCU - Obstetric Critical Care Unit; [#]e.g. valvular lesions, cardiac failure; [$]Continuous positive airway pressure; [+]e.g. coma, brain oedema

The standard of care (administration, medical and nursing personnel care) of patients with SAMM and/or mortality was assessed and classified using the NCCEMD (Saving Mothers Report) criteria template (NCCEMD, 2008; Mantel, 1998). These findings are shown in

Table 14. The SAMM death ratio was 5:1 (20%) in the “Before OCCU” group and 20:1 (5%) in the “After OCCU” group.

Table 14: Classification of the standard of care of patients who had severe acute maternal morbidity

Classification*	Before OCCU#	After OCCU	p-value
SAMM$	46	40	0.44
Suboptimal care, different management would have made no difference to the outcome	12	6	0.01
Suboptimal care, different management might have made a difference to the outcome	18	3	<0.01
Suboptimal care, different management would reasonably have been expected to have made a difference to the outcome	13	2	<0.01

Patients may have more than one SAMM
**Assessed according to National Committee for Confidential Enquiries into Maternal Deaths; #OCCU - Obstetric Critical Care Unit; $Severe acute maternal morbidity (Mantel, 1998)*

After the initial evaluation to determine admission criteria for the OCCU (virtual in the “Before OCCU” group and actual in the “After OCCU” group), newly arising critical incidents and complications (different and subsequent to the admission criteria for the OCCU) were assessed according to general ICU criteria. The template to define critical incidents that occurred in the labour ward (“Before OCCU” group) or OCCU after admission to the area were adapted from the general ICU system of Tygerberg Academic Hospital (personal communication – Dr C Fourie) and are shown in Table 15.

Table 15: Major morbidity in the labour ward ("Before OCCU" group) or in the Obstetric Critical Care Unit after admission

	Before OCCU*	After OCCU	p-value
Cardiac arrest	7	0	0.01
Intubation (emergency and elective)	13	5	0.05
Nosocomial pneumonia	0	2	0.24
Pneumothorax	1	1	1
New onset renal failure	8	1	<0.01
Dialysis	3	0	0.13
Central nervous system#	6	1	0.01
Haemorrhagic shock	5	1	0.01
Shock (septic, cardiogenic)	5	2	0.27
Catheter sepsis	1	2	0.48

**OCCU - Obstetric Critical Care Unit; #e.g. encephalopathy*

Twenty patients in the "Before OCCU" group and 13 in the "After OCCU" group were transferred to general ICU (p=0.21). In Table 8 the data reflecting organ based inclusion criteria and morbidity markers, showed no specific differences. In contrast there was a significant difference in maternal mortality between the groups in the labour ward and OCCU area. In the "Before OCCU" group seven patients died in the labour ward while no patients died in the labour ward or the OCCU in the "After OCCU" group (p=0.01). In addition to the seven maternal deaths, there were another four cases (two in each group) that occurred in the general ICU. The sum of these deaths reflects the total maternal mortality at Tygerberg Academic Hospital during the study period. The numbers and localities of maternal deaths are shown in Table 16.

Table 16: Maternal mortality

	Before OCCU* n=63	After OCCU n=60	p-value
Mortality in labour ward or OCCU	7	0	p=0.01
Mortality in ICU#<72 hours after transfer	1	1	p=1.00
Mortality in ICU>72 hours after transfer	1	1	p=1.00
Total maternal mortality	9	2	p= 0.05$

**OCCU - Obstetric Critical Care Unit; #General intensive care unit;$Odds ratio = 4.8 (95%CI 1-23)*

Greater details regarding all of the maternal deaths are given in Tables 17-24.

Table 17: Characteristics of maternal deaths in the "Before OCCU" group

Allocated maternal death number	Age (yrs)	Gravidity	Parity	Gestation (weeks)	APACHE* Score (0->35)	MODS#	General ICU$ bed available
1	28	2	2	30	11	No	No
2	22	1	1	41	9	No	No
3	31	1	0	24	17	Yes	No
4	29	1	1	36	11	No	No
5	25	4	4	31	16	Yes	No
6	43	4	5	34	14	Yes	No
7	28	2	2	29	22	No	Unknown
8	26	1	0	29	20	Yes	Yes
9	32	3	3	40	23	Yes	Yes

**APACHE - Acute physiology age chronic health evaluation; #MODS - Multiple organ dysfunction syndrome; $General intensive care unit*

Table 18: Causes of mortality and avoidable factors in the "Before OCCU" group

Allocated maternal death number	Primary cause*	Final causes*	Patient avoidable factors*	Administrative avoidable factors*	Medical personnel avoidable factors*
1	Non-pregnancy-related infection: pneumonia	Respiratory failure	No antenatal care	Lack of health care facilities: no ICU& bed Lack of equipment and appropriately trained staff in labour ward	Problem recognition: late recognition of respiratory failure
2	Anaesthetic complications: cardiac arrest in theatre resulting in hypoxic-ischaemic brain damage Pre-eclampsia	Respiratory failure	None	Lack of health care facilities: no High Care Unit bed Lack of equipment and appropriately trained staff in labour ward	Problem recognition: late recognition of respiratory failure. Sub-standard management: failure to resite tracheostomy tube
3	Non-pregnancy-related infection: pneumonia	Respiratory failure associated with renal failure	None	Lack of health care facilities: no ICU bed. Lack of equipment and appropriately trained staff in labour ward	Sub-standard management (correct diagnosis)
4	Hypertension: pre-eclampsia complicated by pulmonary oedema	Respiratory failure	None	Lack of health care facilities: no ICU bed. Lack of equipment and appropriately trained staff in labour ward	Sub-standard management (correct diagnosis)
5	Obstetric haemorrhage: postpartum haemorrhage	Circulatory system: hypovolaemic shock	None	Lack of health care facilities: no ICU bed. Lack of equipment and appropriately trained staff in labour ward. Transport problems delay	Sub-standard management (correct diagnosis)
6	Obstetric haemorrhage: ruptured uterus	Circulatory system: hypovolaemic shock	Delay in accessing medical help	Lack of health care facilities: no ICU bed. Lack of equipment and appropriately trained staff in labour ward. Transport problems: delay in transport from referring hospital.	Sub-standard management (correct diagnosis)
7	Non pregnancy related infections: pneumonia HIV+	Respiratory failure	Lack of information	Lack of equipment and appropriately trained staff in labour ward	Sub-standard management (correct diagnosis)
8	Non pregnancy related infections: pneumonia HIV+	Respiratory failure associated circulatory failure; renal failure	Delay in accessing medical help	Nil	Nil
9	Obstetric haemorrhage: postpartum haemorrhage Hysterectomy	Circulatory system: hypovolaemic shock	None	Transport problems: delay in transport from referring hospital.	Inadequate initial resuscitation

Intensive care unit; #NCCEMD - National Commission for Confidential Enquiries into Maternal Deaths

Because ventilators were not routinely (standard of care) available within the labour ward, patients who decompensated and required intubation were temporarily ventilated using an Ambu-bag® until a ventilated bed became available in the general ICU. This approach is illustrated in Table 19.

Table 19: Management summary of maternal deaths in the "Before OCCU" group

Allocated maternal death number	General management	Ventilation	Inotropes	CVP#/ PAC$	A-line*	Monitor
1	Antibiotics TB treatment Resuscitation	Intubated manual ventilation	No	No	No	SaO_2
2	Resuscitation Tracheostomy in ICU	Failed intubation	Yes	No	No	No
3	Antibiotics Resuscitation	Intubated manual ventilation	Yes	No	No	SaO2
4	Blood pressure control Resuscitation	Manual ventilation	No	No	No	No
5	Resuscitation	Intubated manual ventilation	Yes	No	No	No
6	Resuscitation Intubation	Intubated manual ventilation	Yes	No	No	No
7	Resuscitation	Manual ventilation	No	No	No	No
8	Intubation and ventilation in ICU Inotropic support	Intubated, machine ventilation	Yes	No	Yes	ICU monitor
9	Resuscitation Hysterectomy Blood transfusion	Intubated, machine ventilation	Yes	Yes	Yes	ICU monitor

**Intra-arterial; #Central venous pressure catheter; $Pulmonary artery catheter*

Table 20: Classification of avoidable factors (using the South African NCCEMD* template) in maternal deaths in the "Before OCCU" group

Allocated maternal death number	No suboptimal care	Suboptimal care, different management would have made no difference to the outcome	Suboptimal care, different management might have made a difference to the outcome	Suboptimal care, different management would reasonably have been expected to have made a difference to the outcome
1				X
2			X	
3				X
4				X
5				X
6			X	
7				X
8	X			
9			X	

**NCCEMD - National Commission for Confidential Enquiries into Maternal Deaths*

Table 21: Characteristics of maternal deaths in the "After OCCU" group

Allocated maternal death number	Age (yrs)	Gravidity	Parity	Gestation (weeks)	APACHE* Score (0->35)	MODS#	General ICU$ bed available
1	26	1	0	27	27	Yes	Yes
2	30	2	2	31	31	Yes	Yes

**APACHE score - Acute physiology age chronic health evaluation; #Multiple organ dysfunction syndrome; $General intensive care unit*

Table 22: Causes of mortality and avoidable factors in the "After OCCU" group

Allocated maternal death number	Primary cause	Final causes	Patient avoidable factors	Administrative Avoidable factors	Medical personnel avoidable factors
1	Non-pregnancy related infection: tuberculosis (AIDS)	Respiratory failure with associated renal failure; ARDS*	Delay in accessing medical help; booked late; no anti-retroviral drugs	None	None
2	Hypertensive disorder: acute fatty liver of pregnancy	Liver failure associated with ARDS*; DIC#; renal failure	None	None	Problem recognition: incorrect diagnosis; delay in referring patient

**ARDS - Adult respiratory distress syndrome - ; #DIC – Disseminated intravascular coagulation*

Table 23: Management summary of maternal deaths in the "After OCCU" group

Allocated maternal death number	Ventilation	Inotropes	CVP*/ PAC#	A-line$	Monitoring SaO_2 ECG
1	Intubated, machine ventilation	Yes	No	Yes	Yes
2	Intubated, machine ventilation	Yes	Yes	Yes	Yes

**Central venous pressure catheter; #Pulmonary artery catheter; $Arterial-line*

Table 24: Classification of avoidable factors (using the South African NCCEMD* template) in maternal deaths in the "After OCCU" group

Allocated maternal death number	No suboptimal management	Suboptimal care, different management would have made no difference to the outcome	Suboptimal care, different management might have made a difference to the outcome	Suboptimal care, different management would reasonably have been expected to have made a difference to the outcome
1	X			
2		X		

**NCCEMD - National Commission for Confidential Enquiries into Maternal Deaths*

Basic neonatal outcome data are shown in Tables 25 and 26.

Table 25: Neonatal data at delivery

	Before OCCU*	**After OCCU**	**p-value**
Gestational age (weeks)#	35 (20-42)	34 (20-42)	0.23
Normal vaginal delivery (n)	23	14	0.24
Caesarean section (n)	37	36	0.34
Birth weight (grams)*	2358 (640-4380)	2040 (460-4328)	0.13

**OCCU - Obstetric Critical Care Unit; #Data given as median range*

Table 26: Neonatal outcomes

	Before OCCU*,#	**After OCCU*,#**	**p-value**
Termination of pre-viable pregnancy (n)	3 / 62	5 / 56	0.38
Apgar <7 at 5 min (n)	9 / 43	9 / 38	0.61
High dependency neonatal unit (HDU) (n)	12 / 56	10 / 53	0.73
Neonatal intensive care unit (n)	3 / 56	3 / 48	0.84
HDU for low birth weight (n)	8 / 48	13 / 43	0.11
Neonatal death >27 weeks (n)	3 / 60	2 / 56	0.71
Intra-uterine death (IUD) (n)	11 / 64	8 / 56	0.67
Neonatal hospital stay in days; median (range)	6 (0-36)	8 (0-34)	0.67
Abruptio placentae IUD (n)	9 / 63	3 / 60	0.08

Some of the neonates were born in referring hospitals and data was not available.
**OCCU - Obstetric Critical Care Unit; #numerator (n) / denominator (available data n)*

4.6 Discussion

This study evaluated the impact of managing critically ill obstetric patients in a level 2/3 OCCU compared to a standard labour ward. It showed a decrease in maternal mortality and morbidity. A summary of the main findings of this prospective study evaluating the outcomes in the "Before OCCU" and "After OCCU" group will now briefly be discussed with a more detailed discussion to follow.

This study demonstrated a statistically significant decrease in maternal mortality in critically ill obstetric patients (with existing or developing organ dysfunction) when managed in a dedicated level 2/3 OCCU compared to a standard South African tertiary hospital labour ward (Table 16). Significantly more patients with SAMM died in the "Before OCCU" group. The SAMM mortality ratio in the "Before OCCU" group was: 1 death per 5 SAMM compared to that in the "After OCCU" group, which was 1 death per 20 SAMM. Significantly more patients in the "Before OCCU" group suffered from new onset renal failure, haemorrhagic shock and central nervous system complications after they had been admitted to labour ward compared to patients admitted to OCCU in the "After OCCU" group. The neonatal outcomes in terms of morbidity and mortality did not differ significantly between the two groups.

Evaluation of the results showed that the two groups were comparable in terms of baseline characteristics, organ dysfunction on admission and in terms of markers of severity of illness (SAMM and APACHE scores). The most common causes for admission in both groups were complications of pre-eclampsia, respiratory failure, haemorrhage and sepsis. The similarities between the two groups were as follows: the infrastructure and engineering services available (see Chapter 3), availability of a fully equipped basic resuscitation trolley and academic qualifications of doctors and midwives. The ideal staffing norm (when available) of one midwife to two patients, availability of an anaesthetist on call for the obstetric theatre and availability of multi-disciplinary consultation including ambulance services and the possibility of ICU transfer (depending on bed availability) were also comparable. The main differences between the groups were in the patient management. Management of patients in OCCU was provided by midwives and doctors with additional formal and informal basic critical care training together with the availability of fixed multi-port critical care patient monitors. Management, education, guidelines and quality assurance was done separately from the labour ward by the OCCU nursing manager and an obstetric consultant.

It could be argued that the positive results of this study were merely due to the "Hawthorne effect". While this may certainly have contributed, the positive results exceeded this explanation alone. The study took place in the context of a continuous education and training environment and therefore both "Before OCCU" and "After OCCU" groups would have been subject to its effect. The relationship between the researchers and the labour ward team in the clinical service areas during the study, was a continuous co-operative partnership and the practice of labour ward registrars is continuously monitored. While no extra doctors were employed for the establishment of the OCCU, three new nursing posts (one sister per session), including that of unit manager were created. This affordable staff increment together with the additional teaching new protocols, increased bed capacity (2-3 beds) and the new OCCU model persé formed the "DNA" of the new unit and together facilitated the pleasing results.

The indications for the monitoring of oxygen saturation, respiratory rate, ECG, intra-arterial blood pressure and central venous pressure were similar in both groups. However, fewer patients received the indicated monitoring in the standard labour ward because this ward lacked appropriate monitoring facilities. One of the explanations for the better primary outcomes in the OCCU group lies in appropriate monitoring and responses. This plays a pivotal role in the management of the critically ill patient. When organ system dysfunction is recognised it is important to resuscitate immediately, support the organ system, identify the underlying cause and provide further appropriate management. Indicated medical interventions according to international standard criteria did not differ between the groups. However, in the "Before OCCU" group many patients did not receive the indicated medical care in terms of airway, respiratory and circulatory support. The most common organ system dysfunction was respiratory distress due to pulmonary oedema and pneumonia. CPAP machines and a ventilator were available in the OCCU but not in the labour ward to patients with respiratory dysfunction. In this study early respiratory support in the form of BiPAP, CPAP and at times ventilation most certainly contributed to fewer mortalities in the "After OCCU" group while the complication rates of additional therapeutic interventions such as CVP's, a-line insertions, CPAP ventilations and haemodynamic support were low in the "After OCCU" group.

There were necessary transfers to the general ICU for both groups which show the importance of having access to such an ICU. However, in the "Before OCCU" group there were no general ICU beds available in five cases where critically ill obstetric patients did have an indication for such transfer. Unfortunately all of these women deteriorated and died in the labour ward despite the best attempts with inadequate facilities. In the "After OCCU" group four patients had to be resuscitated and ventilated and met criteria for general ICU transfer, but again there were no ICU beds available. This necessitated there managed in OCCU which is officially a non-ventilatory unit. However, a ventilator was available for emergency intubation and ventilation while waiting for theatre or general ICU transfer. The study shows that it was possible to upgrade to an emergency level 3 critical care unit and none of these women died in the OCCU.

In the "Before OCCU" group, nine patients died (seven in the labour ward and two after transfer to the general ICU). In contrast to this, no patients in the "After OCCU" group died in the labour ward (including OCCU), although two patients were subsequently transferred to the general ICU and died there after transfer (Table 16). Significantly more maternal deaths in the "Before OCCU" group were classified as preventable due to inadequate facilities. The establishment of an OCCU (within the labour ward setting) with the aim of decreasing maternal morbidity and mortality has thus been successful in the Tygerberg Academic Hospital. Improved outcomes result from the creation of appropriate capacity and the superior patient care in the "After OCCU" patient group. This study demonstrates the importance of having a critical care unit staffed by doctors and midwives with in-service training and/or experience in critical care situated within the labour ward. Patient survival depends on early detection of illness, appropriate and skilled monitoring and respiratory and haemodynamic managements and care. Monitoring leads to appropriate management of the pathophysiological condition of the patient. Interventions such as early respiratory, airway and circulatory support are essential to patient survival. The ability to perform emergency invasive ventilation during resuscitation and when no general ICU bed is available is essential. For this reason it is important for an OCCU to have the ability to upgrade temporarily to a level 3 service. Obstetric emergency and critical care education and training as well as monitoring and respiratory support equipment is essential to providing a quality emergency care service which ultimately leads to a reduction in maternal mortality and morbidity. Establishing an OCCU according to the methods followed provides an ideal environment for quality emergency care and the blueprint (Chapter 3) can be reproduced in oher similar hospitals.

4.6.1 Demographics

The author could not identify any other peer-reviewed comparative or randomised studies on the impact of an obstetric critical care unit in a labour ward. Once the OCCU had been established, it would not have been ethical to randomise patients to treatment in the OCCU or labour ward as a sufficient number of reported case series demonstrate improved outcomes when patients are managed in obstetric critical care units (Mabie & Sibai, 1990; Johanson et al., 1995; Zeeman et al., 2003; Ryan et al., 2005). For this reason a thorough prospective "Before OCCU" evaluation was performed prior to the establishment of the OCCU to provide a comparative group for the "After OCCU" cases.

The time interval between auditing the groups was only one year. The reason for auditing the outcomes in the intervention group exactly one year later was to account for the seasonal variation in the pattern of patient numbers and pregnancy complications such as pre-eclampsia, experienced in this hospital, which was also the finding in other subtropical regions (Te Poel et al., 2011). This precaution served its purpose as the numbers of deliveries, primary causes and numbers of admissions were similar. The drainage area, population numbers and socioeconomic status remained similar during 2005 and 2006. Johanson et al. examined the need for and admission pattern to obstetric intensive care services at the Groote Schuur Hospital OCCU in the Cape Peninsula of South Africa (1995). In this case series over a one year period during 1992, the admission pattern, interventions and outcomes of 200 patients admitted to the OCCU located in the labour ward of Groote Schuur Hospital, were described. Twenty eight patients were transferred to the general ICU, mainly for ventilation. There were seven maternal deaths reported in this group of patients (causes of mortality will follow in this discussion). This hallmark study provides a useful point of reference in time for the obstetric patients in the Western Cape who required critical care. Between 2001 and 2006 the population in the Western Cape increased by 1 000,000 (Saving Mothers, 2008) and many patients from low socio-economic migrated from the Eastern Cape province and even other African countries to the Western Cape Province of South Africa. The growing HIV epidemic in South Africa also impacted severely on the already limited critical care resources. This presented new challenges to maternal health care for the growing population especially in terms of emergency obstetric care. Health interventions must be shown to be effective and sustainable. It was therefore important to assess whether an obstetric critical care unit could be established and provide this much needed additional critical care resource.

A strength of this study was that it was possible to compare two similar groups with and without critical care intervention. The point of entry for all patients into the obstetric department was the same, ie the obstetric admission area and then admission to the labour ward. The results indicated that the two groups were comparable in terms of maternal baseline characteristics (Table 1), organ system dysfunction, direct obstetric causes of admission (Table 4), the incidence of SAMM at admission and median APACHE II score. The APACHE II score is currently used in general intensive care to predict the risk of mortality in patients admitted to the general ICU. The APACHE II was found to overestimate the risk of dying in an obstetric population. This may be due to the changes in maternal physiology and a younger population. Its use, however, is still recommended for scoring the severity of illness in critically ill obstetric patients and remains valuable (Lapinsky et al., 2011). It can also be used to compare severity of illness when comparing different case series reports. Paruk developed a clinical risk scoring system specifically for pregnant women which was evaluated in South Africa, this scoring system was not used in this study because it was developed specifically for patient with eclampsia and therefore lacks a broader application. It is however promising and must be further evaluated in other settings (Bhagwanjee et al., 2000). Patients with SAMM criteria are at increased risk of dying, which was estimated to be 1:3.3 in a South African population (Vandercruys & Pattinson, 2002). The high incidence of SAMM on admission in both groups demonstrates the similar severity of critical illness in both groups. APACHE scores were similar and high in both groups which demonstrated that both groups were at high risk of mortality, and needed specialised care.

From 1999 to 2007 there was a steady increase in the incidence of HIV/AIDS (Saving Mothers, 2008). More patients in the “After OCCU” group had non-pregnancy related sepsis (Table 4). Although the incidence HIV infection was rising at the time, this finding could be explained by increased awareness and more special investigations performed in order to diagnose HIV infection in the later group. With the presence of significantly more severe non-pregnancy related sepsis (associated with HIV/AIDS) in the “After OCCU’ group, the outcomes in this group could justifiably have been poorer than in the “Before OCCU” group. However, the outcomes were significantly better, thereby further supporting the importance of the OCCU interventions (Merino, 2007; Saving mothers, 2008) An important lesson that was learned in the course of this study, was that even in cases of advanced HIV disease during pregnancy, early and appropriate management improved outcomes. Therefore HIV/AIDS should not be used as a discriminating factor when allocating critical care resources.

In both the “Before OCCU” and “After OCCU” groups the percentage of patients referred to Tygerberg Academic Hospital who required critical care was 3.5%. This incidence of obstetric patients requiring obstetric critical care is higher than other published obstetric critical care case series. Basket (2008) reported an incidence of 0.9-1.7% of obstetric patients requiring obstetric critical care, while 5-11% of these patients were ultimately transferred to a general ICU. In the “After OCCU” group 13 (22%) women were transferred from the OCCU to the general ICU, but it should be remembered that the “After OCCU” study only extended over a period of three months.

The antenatal admissions were higher than postnatal admissions in both groups (Table 1). Once the OCCU was established and functioning, antenatal patients with morbidity were detected earlier, allowing for earlier access to critical care. The time delay between identifying a patient at risk or with a complication, until definitive management, will clearly impact on outcome (Pattinson, 2013; Wheatly 2010). The antenatal OCCU admission rate (51%) was higher than other similar reports. Ryan et al. reported an 18% antenatal admission rate, Zeeman et al., a rate of 20%, and Saravanakumar, an antenatal admission rate of 11.3%. In a published case series in which obstetric patients admitted to general ICU's were reviewed, it was found that the majority of ICU transfers (77%) occurred post-partum (Basket, 2008). It is beneficial to manage a critically ill antenatal patient in an OCCU as opposed to a general ICU where there is usually limited capacity to monitor and care for the foetus (Basket, 2008). A question that must also be asked is whether most complications occur post-partum or do they start during the antenatal period but only manifest or are detected postnatally? In this study special care was taken to assess patients at risk of developing organ dysfunction during the antenatal period. When morbidity was detected the patient was transferred expeditiously to OCCU where management was instituted even before delivery.

In this study the primary reasons for organ dysfunction and therefore admission to OCCU were hypertensive disorders, obstetric haemorrhage, sepsis and medical disorders (eg cardiac pathology). This pattern of disease in both the "Before and After OCCU" groups was similar to the reported pattern of maternal deaths for the Western Cape Province as a whole during the study period (Saving Mothers, 2008). The major causes of morbidity were also similar to those of other studies describing admission to obstetric critical care units.

Sepsis was a common cause of admission, being present in 19/30 (32%) of cases in the "After OCCU" The incidence of sepsis as a primary indication for admission to a OCCU was also high in a Brazilian study (Oliveira Neto, et al. 2009) compared to other first world countries, The study by Johanson et al. did not specifically reported the incidence of sepsis out of 258 OCCU admissions during one year in 1992; however one patient developed nosocomial sepsis and died. Five patients were admitted under the heading of miscellaneous infections and 14 patients had respiratory complications due to asthma, sarcoidosis, scoliosis and an unspecified number of pneumonias, but no HIV or AIDS cases reported. In the American 1990 study Mabie and Sibai reported nine patients admitted with sepsis out of 200 admissions. During 2003

Zeeman et al., 14 cases of puerperal sepsis and 10 patients with pneumonia out of 483 patients admitted to a level 2 critical care unit. Thirty-four women were transferred to general ICU when indicated. In another reported case series describing the epidemiology of 1359 admissions over a four year time period 2003-2007 to a labour ward OCCU in the United Kingdom reported: one case of TB meningitis; four cases of genital tract sepsis, four pneumonia cases and seven patients were transferred to general ICU for sepsis. There were no reports of any HIV+ patients admitted. (Saravanakumar et al. 2008). In a Brazilian study performed over four years in a tertiary stand alone Womens Hospital with an ICU, the incidence of obstetric patients admitted with severe sepsis was 3.8%, 26 cases out of 673 admissions and only one reported case of HIV/ AIDS. Vaso-active drugs were administered in the unit but the incidence and indication were not specified. The mortality rate for sepsis were one death per six admissions (four deaths). It is important to see this in context. The unit functioned as ICU and had to manage patients with multi organ dysfunction/ failure and they did not have the availability to transfer to other ICU's (Oliveira Neto et al., 2009). In other case series hypertensive disorders were also the main leading indication for care in a general ICU (Cande & Smulian, 2010; Senanayake et al., 2013). The high incidence of HIV infection in our study groups and more so in the "After OCCU" group probably contributed to the higher rate of sepsis. In the most recent UK Saving Mothers Report the incidence of pregnancy-related sepsis was increased compared to the previous enquiry. The reason for this increase is uncertain (CMACE, 2011).

4.6.2 Haemodynamic monitoring

The chief reason for improved outcomes in the "After OCCU" group must be better medical management. It is therefore important to discuss the differences in the interventions management of patients between the two groups. The patients in the "Before OCCU" group were managed in a standard tertiary labour ward by medical and nursing staff with appropriate tertiary qualifications in obstetrics but no training or expertise in critical care. Limited monitoring equipment was available in the form of pulse oximetry, and the management policy was to take manual measurements of blood-pressure and pulse. Respiratory rate was infrequently monitored due to the lack of understanding of the importance of this vital sign. There was, however, a policy for the specific management of patients with pre-eclampsia in the labour ward similar to other South African protocols (Moodley 2008; Lombaard et al., 2005). The patients in the "After OCCU" group were managed in the OCCU by personnel with additional training according to critical care management protocols such as goal-directed resuscitation (Marino, 2007) and the surviving sepsis campaign (Dellinger et al., 2008). An organ based evaluation approach was followed and maternal monitoring systems as well as BiPAP/CPAP non-invasive ventilators were available. Special attention was given to ensure adequate oxygen delivery by improving the cardiac output, haemoglobin levels and adequate oxygen saturation (Price, 2008). The indications for specific monitoring interventions were determined using the same criteria in both groups. In the "Before OCCU" group significantly fewer patients were able to receive oxygen saturation monitoring, central venous pressure or intra-arterial blood pressure monitoring (Table 9). However, once patients were in the OCCU ("After OCCU" group), the placement of intra-arterial lines, when indicated, allowed for accurate and continuous blood pressure monitoring and frequent blood gas sampling (Mireno 2007). There were two (4.3%) complications (superficial site infections) associated with 47 arterial line insertion in the "After OCCU" group which were successfully treated with antibiotics. A single pneumothorax occurred after 37 CVP insertions. The safer internal jugular vein was the preferred entry point. Sixteen patients in the "after OCCU" group were admitted with pulmonary oedema. There there were no cases of iatrogenic fluid overload and new onset pulmonary oedema listed under complications of using CVP monitoring (Table 9). This was probably due to the protocol of not using a once off CVP value but to administering a 200ml fluid bolus and monitoring the change in central venous pressure. The incidence of dialysis for renal failure in the "After OCCU" group was 0 compared to five in the "Before OCCU" group. The authors found that the approach of monitoring the CVP with caution was safe for the management of administering fluid and of inotropes. Larger numbers are needed to exclude complications due to this CVP management approach in resistant oligo-uric patients with pre-eclampsia and will be evaluated in Chapter 5. Pulse oximetry, intra-arterial lines and central venous pressure catheters were also frequently used in the other reported OCCU case series. The use of invasive monitoring will only be briefly discussed in this chapter and in more detail in Chapter 5. Mabie & Sibai reported in 1990 the placement of 151 arterial lines out of 200 admissions with a description that complications were rare but did not specify what they were (1990). Johanson et al. placed 94 arterial lines without any complications and 106 central venous catheters out of 258 women admitted to their Unit (1995). The complication rate of the insertion of standard size CVP catheter or sheath central catheter (79 cases) was low and included two cervical haematomas, two extra vascular infusions (not specified, probably pneumothorax) and one skin entry point cellulitis.

More recently in a United Kingdom level 2 OCCU Saravanakumar et al. (2008), reported intra-arterial monitoring in 303 patients out of 1359 admissions (22.3%) and 7.1% of patients required a CVP and a-line for monitoring. Indications for arterial lines were mainly pre-eclampsia, haemorrhage and probably cardiac disorders as cardiac disorders were the main indication for admission in non-obstetric causes. This incidence of invasive monitoring is more in line with the index study and the studies discussed above.

In the 2003 case report by Zeeman et al., 34 patients out of 483 admissions were transferred to general ICU, where 12 patients received arterial lines, 14 patients received CVP lines and only four patients received pulmonary artery catheters. The authors did not specify if arterial lines and CVP lines were placed in the level 2 OCCU. In an Irish study the reported incidence of arterial and central venous pressure monitoring in the level 2 critical care unit were also low, only four CVP's and four intra-arterial lines were placed in the OCCU out of 123 obstetric patients admitted over four years during 1996-1998 (Ryan et al., 2000). The low incidence of the use of invasive monitoring is different when compared to the high incidence of the use invasive haemodynamic monitoring in the index and other studies discussed before. The reason for this difference is probably differences in the severity of disease, threshold of general critical care transfer and the availability of general level 2 and 3 critical care units, where these procedures can be performed when indicated. (Mabie & Sibai, 1990; Johanson et al., 1995; Zeeman et al., 2003). It is important to take note of the findings of a Brazilian study reported in 2009, this study reports on admissions of obstetric patients to a ICU in a stand alone Women's Hospital with a tertiary obstetric service. In this report 673 women with severe morbidity were admitted during 2002-2007 and monitoring and management required the placement of 98 central venous lines, ten arterial lines, the reasons for the higher incidence of CVP vs intra-arterial monitoring were not discussed (Oliveira Neto et al.,2009). The index study clearly showed that the standard labour ward was unable to provide appropriate monitoring and management of critically ill patients. Monitoring is one of the cornerstones of critical care management, thereby ensuring early recognition and management of abnormal physiological variables. It also provides the opportunity to measure the impact of interventions. Langenegger et al., demonstrated poor correlation between both automated and manual sphygmomanometer blood pressure readings during acute severe hypertension in pre-eclampsia, non invasive blood pressure measurements significantly under estimated the systolic blood pressure readings compared to intra-arterial monitoring (2011). It was not possible to place the indicated amount of pulmonary artery catheters in either group. In the “after OCCU” group (n=60) three were placed with no complications, the main indication being complex cardiac conditions. Eleven patients could have received a pulmonary artery catheter according to the ACOG guidelines, but the numbers are too small to demonstrate any advantages of placing pulmonary artery catheters (Table 9). The small number of placements was probably due to the lack of expertise and the special additional equipment required especially after hours. It demonstrates that even with an OCCU a doctor, technician and nurse experienced in the placement and management of pulmonary artery catheters will be needed. These are not always available. The pulmonary artery catheter was frequently used for haemodynamic monitoring in other OCCU studies with low reported complication rates, Johanson et al. reported 79 pulmonary artery catheters placed (79/258) for mainly refractory severe hypertension, pulmonary oedema and resistant oligo-uria. One case of ventricular dysrhythmia required medical treatment. The authors commented that inserting a pulmonary artery catheter provides more detailed information for management, especially due to the fact that the correlation between CVP and wedge pressure is poor, and they found the intervention to be a reliable to guide fluid management in pre-eclampsia (Johanson et al. 1995). Mabie & Sibai reported the placement of 74 pulmonary artery catheters out of 200 admissions. The indications were oligouria, pulmonary oedema, massive haemorrhage, adult respiratory distress syndrome, class 3 and 4 cardiac disease (1990). The complications were rare but not specified (Mabie & Sibai 1990). The placement of pulmonary artery catheters are much more frequent in the 1990’s studies compared to the more recent studies. It should be noted that in recent literature the usefulness of pulmonary artery catheters is controversial, this will be further discussed in Chapter 5 (Yu et al., 2003).

4.6.3 Haemodynamic management

Table 11 demonstrates no significant differences in the indications for drug haemodynamic support between the two groups. The establishment of the OCCU provided guidelines for the use of intravenous vasoactive drugs, ie labetalol, hydralazine, inotropes, or nitrates although these drugs were available to both groups. However, for the reasons explained, such as lack of safety, monitoring and nursing expertise, significantly more patients in the "Before OCCU" group did not receive the indicated intravenous drugs. In the index study the indications and use of vasoactive drugs in our study of obstetric patients with organ dysfunction, sepsis, severe bleeding, cardiac failure in a time period of only three months were nine out of 60 admissions who received inotropic support. Thirteen patients received IV nitrates for pulmonary oedema or cardiac failure (Table 11).

In the 1990 American study nine patients had sepsis, an unspecified number of patients had septic shock but the number of patients who received inotropes were not specified (Mabie & Sibai 1990). In the South African 1995 study the inotropic support was not specified, however three patients were transferred to general ICU for sepsis and inotropes were probably used in the OCCU as well. Di-hydralizine infusions were used for resistant severe hypertension control (Johanson et al., 1995).

Oliveira Neto et al as previously discussed reported on 26 obstetric patients admitted with severe sepsis to a stand alone Womens Hospital ICU. Inotropic and vasopressor support were provided but the numbers were not specified (Oliveira Neto et al., 2009). In the index study it was important to have the infrastructure and skill to administer and monitor vasoactive infusions (inotropes, vasopressors), ie have invasive monitoring, especially for septic and cardiac patients, since these patients could often not be transferred to general ICU.

The use of haemodynamic support (inotropes and vaso pressors specifically) in the OCCU level 2 models with immediate general ICU availability will now be discussed. In the Zeeman et al., study only six patients were transferred for inotropic and vasopressor, in the index study it was possible to safely administer inotropes in patients with severe sepsis and cardiac failure in nine patients, only four patients were later transferred to ICU, mainly for multi-organ failure or ventilation (table 11 & 13).

Ryan et al. (2000) reported on 123 patients admitted to a two bedded level 2 OCCU, arterial line and CVP monitoring was available as discussed above. Haemodynamic instability were present in 106 patients mainly due to haemorrhage, nine of these patients were transferred to ICU. The authors did not report on the use of inotropic support. Inotropic support for cardiac support or sepsis without requiring ventilation and multiple organ dysfunction can porbably be administered in such a unit described by Ryan et al., this will however depend on the unit's protocols and ICU availability (2000). Saravakumar et al. did not report on the use, indications or incidence of inotropic support, however 29 patients had sepsis (2%) and 111 cardiac patients (8%) were admitted and it was probably possible to use inotropes in their unit (2008).

It is clear from the results of this study that the labour ward alone was not able to provide this level of indicated haemodynamic support. Another possible reason for the lack of interventions is that the diagnosis was not recognised.

4.6.4 Respiratory support

A frequent organ dysfunction in both groups involved the respiratory system, secondary to pre-eclampsia with pulmonary oedema or pneumonia. Respiratory support was often indicated in both groups (Table 10). Again fewer patients in the "Before OCCU" group were able to receive the indicated respiratory support. Timely CPAP support or BiPAP can significantly decrease the need for invasive ventilation (Plant et al., 2000). CPAP and BiPAP were available for the "After OCCU" group and decreased the need for invasive ventilation and ICU referral (Table 15). Six patients (Table 13) in the "Before OCCU" group were transferred to the general ICU to receive CPAP only. CPAP is not a complex intervention and can be safely provided in an OCCU with the appropriate equipment. The labour ward ("Before OCCU" group) was only able to provide an oxygen face mask once respiratory distress was detected. The index study demonstrated that it was possible to intubate patients in the labour ward (Table 10), however, the mortality was higher in the intubated "Before OCCU" group. Imminent respiratory failure and arrest was often diagnosed late, non invasive ventilation was not available and the majority of these patients were intubated late. In the "Before OCCU" group there were no ventilators routinely available in the labour ward and the staff lacked the experience to use them. These intubated patients could only be ventilated with manual resuscitators, resulting in suboptimal ventilation in patients with conditions such as pulmonary oedema, acute lung injury and pneumonia. When no ICU beds were available ventilation using manual resuscitators was required until such beds became available. This did not always happen quickly. Seven patients died from cardiac arrest shortly after intubation in the labour ward whilst being ventilated as above.

The establishment of the OCCU created a heightened awareness for detecting respiratory complications. When a patient with respiratory distress is not rapidly supported and stabilised the respiratory muscles become fatigued and hypoxic leading to the development of cardio respiratory arrest. In the “After OCCU” group, respiratory failure was detected early and non-invasive ventilation was applied when indicated. If intubation was required and no general ICU bed was available it was instituted timeously, followed by ventilation in the OCCU until a general ICU bed became available. Even though the OCCU is not classified as a primary invasive ventilatory unit it was possible to upgrade to a level 3 OCCU when emergencies required this. The doctors and nurses were trained in basic ventilation skills and if no ICU bed was available they were safely and effectively ventilated in OCCU. Continued positive airway pressure and BiPAP are sentinel functions of a modern OCCU, as respiratory failure is common and these non-invasive forms of ventilation can prevent the well-known complications of baro-trauma, volu-trauma, bio-trauma and ventilator-associated pneumonia that are common in intubated patients (Hess, 2011). Respiratory failure was common in the earlier similar studies by Johanson et al. (1995) and Mabie & Sibai (1990), as well more recent OCCU reports (the study by Saravakumar et al.; Ryan et al.; Zeeman et al.) The use, numbers and advantages of CPAP and non-invasive ventilation were not reported on in these studies but intubation and mechanical ventilation were frequently needed. Mabie & Sibai reported 24 patients who required mechanical ventilation, six of these patients were transferred to general ICU, they were able to successfully ventilate patients who required short term ventilation. In the 1995 South African study Johanson et al. reported 28 out of 258 women required mechanical ventilation, 24 of these women were transferred to general ICU for ventilation. Indications for ventilation was pre-eclampsia and brain oedema, pulmonary oedema, three patients with sepsis, two patients with abruption placentae and then medical disorders (Johanson et al., 2005). In more recent studies the need for intubation and mechanical ventilation was an indication for ICU transfer and this is ideal when appropriate general intensive care resources are readily available (Zeeman et al., 2003; Ryan et al., 2005). In the public health care sector of South Africa a critical shortage of ICU beds exists and it is therefore often not possible to transfer an obstetric patient with an indication for ventilation (Mathiva, 2002; Naidoo, 2013).

A recent audit of critical care resources in South Africa revealed that even if public and private critical care resources are combined a shortage of beds still exists (Naidoo 2013).

Mabie & Sibai (1990) and Johanson et al. (1995) did have the capacity to institute short term ventilation (<48 hrs); however it was still necessary to transfer patients where more advanced invasive ventilation was indicated or where prolonged ventilation was anticipated.

In the index study, the provision of CPAP and non invasive Bi-PAP for patients in the "After OCCU" group with pulmonary oedema and pneumonia contributed to fewer cases of respiratory arrest, emergency intubation and subsequent need for transfer to ICU for ventilation. The 1995 South African report by Johanson et al., as well as the Brazilian report by Oliveira Neto et al., reported on the availability of CPAP and will be discussed in detail in Chapter 5. Blood gas monitoring is essential to the assessment and management of respiratory distress. Respiratory failure is one of the leading final causes of mortality amongst pregnant women in South Africa for both obstetric and non-obstetric-related conditions (Saving Mothers, 2008-2010). Substandard management and lack of critical care facilities were common avoidable factors in maternal deaths in the "Before OCCU" group.

The experience of the Tygerberg OCCU demonstrates that it is safe and relatively simple to institute early respiratory support therapy with CPAP or Bi-PAP. This respiratory support could be implemented in other units and would contribute to decreasing maternal mortality in patients with early respiratory distress. Another benefit would be to decrease the pressure on general ICU beds, a critically scarce resource in South Africa (Naidoo, 2013).

4.6.5 The Obstetric Critical Care Unit in the management of severe acute maternal mortality

In the index study the standard of care received by patients who had suffered a SAMM and or mortality in the "Before and After OCCU" groups was assessed according to the SA NCCEMD into maternal deaths classification system (Table 14). This classification was also used by Mantel et al. 1998 to assess the standard of care of patients who suffered SAMM. This assessment of avoidable sub-optimal care was performed by the principle author. Although the principle author is experienced, the judgements are subjective and may therefore by subject to bias. There were more maternal deaths in women with SAMM in the "Before OCCU" group, when compared to the “After OCCU” group (p=0.04 [one tailed Fisher exact test] p=0.05 [two tailed Fisher exact test]). Significantly more patients in the “Before OCCU” group had suboptimal management and the consequence of this may be reflected in the higher maternal mortality and morbidity.

In the index study the SAMM:death ratio in the “Before OCCU” group was higher, 5 SAMM:1 death (20%) compared to the SAMM:death ratio in the “After OCCU” group which was surprisingly low at 20:1 (5%). Mantel et al. audited SAMM in the Pretoria area in South Africa and reported a SAMM:death ratio of 5:1 (1998). Which was the same as the “Before OCCU” group.

In another developing country Brazil, a case series reported on 933 patients admitted with SAMM to a level 3 OCCU (obstetric intensive care unit) in Recife. In this case series 22 women died (2.4%) with no transfers to a general ICU. The SAMM criteria varies per study, however in this Brazilian study the SAMM: death ratio was only 1:42 which indicates good maternal critical care management in their level 3 OCCU (Amorim et al., 2006). Moraes et al., reported an audit on severe maternal morbidity in the city of Sau Luis (Brazil). The one year audit was carried out in two High Risk Maternity Hospitals and the two respective general ICUs in the region. These hospitals did not have dedicated obstetric critical care units. One hundred and twenty one patients with morbidity were included. Four of these patients later died in the general ICU. However looking closer, only 29 (23.8%) of these patients met the Mantel SAMM criteria (Mantel et al., 1998). The calculated Mantel SAMM: death ratio in the region was then 7:1. (Moraes et al., 2011).

SAMM survival is a good indicator of the quality of patient management (Say et al., 2009). In the index study the SAMM criteria of Mantel were followed. There is a need to standardise criteria for maternal “near miss” or SAMM in order to provide a standard tool for monitoring of the quality of maternal health care. The WHO has proposed a new near miss or SAMM classification system based on clinical criteria, laboratory based criteria and management based criteria, but this classification system was not available at the time of the audit described here (Say et al., 2009). The index study demonstrates improved outcomes for patients with SAMM when managed in a dedicated level 2/3 OCCU with appropriate management as opposed to care in a secondary/tertiary labour ward, taking into consideration the limited availability of general ICU beds for both groups of patients. The finding of a low mortality rate in the "After OCCU" group is of utmost significance. It demonstrates that, if appropriate care can be instituted timeously, and the unit retains the ability to upgrade to temporary level 3 critical care status, maternal mortality can be reduced.

A careful discussion of the cases of mortality is warranted. The most common cause of maternal mortality in the "Before OCCU" group was non-pregnancy-related sepsis, specifically pneumonia. Three of these patients had deteriorated in the labour ward to the point of respiratory arrest followed by cardiac arrest. At the time no ICU support was available. When patients develop respiratory failure, hypoxic cardiac arrest may follow and the risk of mortality is high if there is no available support and facility for critical care management. It is important to note that the leading reported cause of maternal deaths in the South African Saving Mothers Report of 2011 was also non pregnancy related sepsis which includes pneumonias (40.5%) (Saving Mothers, 2012). One patient in the "After OCCU" group with AIDS and pneumonia and consequent respiratory failure was electively intubated, ventilated and transferred to the general ICU where she nevertheless died after 72 hours due to the severity of her disease. This illustrates the fact that even with the provision of additional critical care facilities, not all such deaths can be prevented.

4.6.6 Haemorrhagic shock

Throughout the study a modern transfusion service was available in the hospital. In the "Before OCCU" group there were three patients who died due to postpartum haemorrhage. In one case a patient developed class four haemorrhagic shock but resuscitation in the labour ward was unsuccessful. There was no intensive care support available. In the second case the patient suffered uterine rupture in a peripheral hospital. When she arrived at Tygerberg Academic Hospital she was in class four haemorrhagic shock and resuscitation in labour ward was unsuccessful. The third patient also developed post-partum haemorrhage in a peripheral midwife-led obstetric unit. She was transferred to Tygerberg Academic Hospital, resuscitated and a hysterectomy was performed, but she developed multi-organ failure and although she was transferred to a surgical ICU, she died. When multi organ failure develops after a complication such as severe prolonged haemorrhagic shock the risk of mortality and morbidity is high even when such a patient are admitted to a surgical ICU. In the Saving Mothers Report key recommendations on haemorrhage, the appropriate skills training of personnel to perform early emergency resuscitation, availability of blood and early transfer (transport) is highlighted as interventions to decrease mortality (Saving Mothers, 2012). The impact of appropriate management of ambulance transport services during 2011 in the Free State Province in South Africa led to a decrease in maternal mortality (Schoon, 2013). Early appropriate emergency care of obstetric haemorrhagic shock and effective transport is essential to improve the outcome in this group of patients and other obstetric patients with complications.

No patients in the “After OCCU” group died of haemorrhagic shock. Because haemorrhagic shock in pregnancy is often occult and therefore underestimated, it is of vital importance to recognise the degree of shock early and perform goal-directed resuscitation in a suitably equipped area such as an OCCU. Emergency surgical control of bleeding is necessary if there is no response to non surgical treatment measures such as oxytocin (Francois Karrie, 2004; Marino, 2007). In South Africa 14% of all maternal deaths are due to postpartum haemorrhage. The majority of these deaths were understandably classified as avoidable (Saving Mothers, 2011). In patients with advanced haemorrhagic shock the chances of intact survival are always greater when the actions provided by an advanced level 3 critical care unit are immediately available.

4.6.7 Pre-eclampsia

One patient in with pre-eclampsia in the “Before OCCU” group developed pulmonary oedema, respiratory failure and then respiratory arrest. It is of utmost importance to train staff to recognise critical illness early and initiate appropriate management as soon as possible in order to prevent further deterioration. Again there was no ICU support available for further management and she suffered cardiac arrest soon after intubation. The advantage for the “After OCCU” group was that patients with the same condition were recognised, diagnosed and managed early. In South Africa during the 2008-2010 triennium, 14% of the maternal mortalities were secondary to the complications of pre-eclampsia. Although the establishment of an OCCU is of great benefit, this alone is not enough. The training of obstetric personnel to recognise risks and respond appropriately and early, remains vitally important. The final recorded mortality in the “Before OCCU” group was a patient with severe pre-eclampsia who suffered a high spinal block in theatre and developed cardiac arrest. She was resuscitated and transferred to ICU but she also developed hypoxic encephalopathy in the

ICU. She later required a tracheostomy for long term airway protection and was transferred to the labour ward for step down care. Unfortunately her tracheostomy dislodged, reinsertion failed and she demised in the labour ward. The important point to note here is that an OCCU can also serve as an essential step down facility for patients transferred from a busy general ICU. In the "After OCCU" group a patient was transferred from a referring hospital with AFLP (Acute Fatty Liver in Pregnancy). On arrival at Tygerberg Academic Hospital she had respiratory, renal, haematological and liver failure. She was stabilized in the OCCU and then transferred to the medical ICU but her prognosis was very poor and she died in that unit.

It is important to differentiate between patients who developed severe morbidity in peripheral units referring to Tygerberg Academic Hospital and those cases that developed morbidity in the labour ward of Tygerberg Academic Hospital. The latter case illustrates the importance of an OCCU in providing intensive support for a patient with advanced multi-organ failure. However, as previously stated such support will not save all patients.

4.6.8 Availability of Intensive Care Unit/Obstetric Critical Care Unit beds

Lack of ICU beds was an important preventable maternal mortality factor in the "Before OCCU" group. Most patients in this group had admission criteria for care in the general ICU but could not be admitted due to a lack of available ICU beds. They deteriorated and died in the labour ward. In the "After OCCU" group eight patients had an admission indication for general ICU care but because general ICU beds were unavailable, management was continued in the OCCU. None of these patients in the "After OCCU" group died.

In the previously discussed large South African case series by Johanson et al. that reported on 258 women admitted to a level 3 OCCU in the same city as the index study, seven women died due to the following complications: eclampsia and intra-cerebral haemorrhage; eclampsia and nosocomial pneumonia; cardiac patient despite cardiac surgery; pulmonary embolism; infective hepatitis and liver failure; respiratory arrest in a patient with scoliosis, post partum haemorrhage (after caesarean section). However, although both studies come from the same geographic region, the index study was performed 15 years later and patterns of disease are subject to continues change. This is specifically relevant in the case of the HIV pandemic and the impact on non-pregnancy related sepsis.

The American study reported in 1990 describes seven maternal mortalities out of 200 admissions. The causes of mortality were: ventricular septal defect with Eisenmenger's syndrome, ruptured arterio-venous (AV) malformation, varicella pneumonia, pre-eclampsia and renal failure, breast cancer, pancreatic cancer and thrombotic thrombocytopaenic purpura. It is important to note that six of these mortalities were non pregnancy related. The mortality risk for the ruptured AV malformation, breast cancer and pancreatic cancer is high and probably not avoidable.

Saravanakumar et al. reported their experience of 3551 admissions over 23 years to a level 2 OCCU in which 36 women died. The causes in the 36 mortalities were not specified, however in a more detailed analysis during a four year period from 2003-2007 where 1359 women were admitted to a level 2 OCCU there were no maternal deaths and 39 patients were transferred to general ICU. The decreased mortality rate over the 23 years is probably advances in medical and obstetric care over 23 years (Saravanakumar et al., 2008). Zeeman et al. reported a large case series of 483 women admitted to a level 2 OCCU in the United States of America. Only one patient died due to pre-eclampsia complicated by intra-cerebral haemorrhage in this series but 34 patients were transferred to a general ICU, however in this series only level 1-2 critical care were provided, patients were transferred for invasive monitoring and ventilation. The methods followed in this study represented a well-oiled protocol where patients were quickly identified and transferred to general ICU for level 3 critical care support, when haemodynamic and or ventilatory support was deemed imminent. This model is dependant on unlimited ICU availability. In this study patients could be stepped down from ICU earlier compared to a normal labour ward or ward transfer and thus increase the ICU bed availability (2003). Ryan et al. reported 123 admissions to a level 2 OCCU in Dublin over a four year period and there were no deaths. In this case series critical care support was available on site in the labour ward from hospital intensivists to assist in management in the obstetric level 2 unit, and it was possible to transfer 17 patients early to general ICU where five patients were intubated and ventilated. The availability of intensivists to assist in the obstetric unit is valuable, in South Africa and other lower income countries this is not possible due to the workload of the general critical care units and many countries do not even have intensivists in the general ICU's (Mathiva 2003). In South African public hospitals the ICU bed per population number is as little as 1:42 000 compared to Europe where the average ICU bed per population varies from 1:3427 to 1:8700 (Naidoo et al., 2013; Rhodes et al., 2012). In these cases it is of utmost importance that the obstetricians must become familiar with advanced emergency management including the skill to intubate and ventilate as acute obstetric emergencies can happen suddenly for example, massive post-partum haemorrhage, pulmonary oedema in pre-eclampsia. Patients are also often referred from referring hospitals, deteriorate on the way and then requires intubation, ventilation and resuscitation on arrival. In the index study ICU beds were often not available when required, this led to increased mortality in the labour ward in the "Before OCCU" group. The ability to manage level 3 patients temporarily or during the whole duration of stay contributed to the significant reduction in maternal mortality during the study period. The impact of OCCU's in labour wards provides the opportunity to identify antenatal, intra-partum and post-partum women with or at risk of organ dysfunction, resuscitate patients, treat complications and provide supportive and transfer to general ICU when necessary (Mabie & Sibai, 1990; Johanson et al., 1995; Zeeman et al., 2003; Ryan et al., 2000.; Saravanakumar et al., 2008; Amorin et al., 2006). The impact of of both level 2 and level 3 OCCU's demonstrates low maternal mortlity rates, this is further supported by the finding of a significant decrease in maternal mortality after the establishment of the Tygerberg OCCU described in the index study. Longer term results from the Tygerberg OCCU will be reported on in Chapter 5 of the thesis. In all these case series the importance of the option to transfer ventilated and or patients with multi organ failure to general ICU were highlighted. It is important to note that all these case reports discussed except for Johanson et al., Amorin et al., were mainly from developed countries and in specific areas in the respective countries (Mabie & Sibai, 1990; Johanson et al., 1995; Zeeman et al., 2003; Ryan et al., 2000.; Amorin et al., 2006; Saravanakumar et al., 2008)

In developing countries there exists a critical shortage of ICU facilities, intensivists and nursing staff with an ICU qualification (Naidoo et al., 2013). In South Africa during 2008-2010 53.4 % of maternal deaths were assessed as being avoidable where substandard care probably led to mortality, lack of ICU beds at tertiary hospital level was responsible for 1082 deaths (21.9%). This may also have resulted in more maternal deaths in the referring hospitals and led to late transfers to ICU, which both resulted in high maternal mortality ratios. This was clearly demonstrated in a Nigerian case series in 2006 where 70 obstetric patients were admitted to a tertiary hospital ICU. The indications for admissions were mostly pre-eclampsia, haemorrhage, and sepsis with respiratory failure and or haemodynamic instability. The mortaliy rate in the ICU was 52%. In this report it was emphasised that many women were transferred late, there was a lack of ICU availability. Early recognision, resuscitation and critical care management is important and will decrease mortality and morbidity. Basic emergency care beds and emergency & critical care skills training and morbidity as was done in the index study may also decrease mortality in Nigeria.

Simply reporting on maternal mortality will not decrease mortality. Interventions such as improving early emergency and basic critical care skills training and providing the necessary equipment. The presence of an OCCU in a labour ward has been shown to be an effective intervention as discussed. It provides the opportunity for early interventions, resuscitation, level 2 supportive maternal and fetal care for critically ill patients and then transfer to theatre or level 3 general critical care units when necessary and when it becomes available. When there are no level 3 general critical care beds available it was shown in the index study that even level 3 critical care can safely be provided with low mortality rates (Langenegger et al., 2012).

4.6.9 Pre-eclampsia management aspects

Pre-eclampsia was the leading condition requiring critical care support (Table 3). The basic initial management of severe pre-eclampsia was similar in both groups. Tygerberg Academic Hospital enjoys international recognition for research in this field with the largest published case series on expectant management of early, severe pre-eclampsia being performed there (Hall et al., 2000). As hypertensive conditions of pregnancy, including pre-eclampsia constitute the most frequent direct obstetric cause of maternal mortality in South Africa (Saving Mothers, 2012), the support provided by an OCCU is of the utmost importance. This topic will be discussed in greater detail in Chapter 5.

The actual indications for patients with pre-eclampsia being admitted to OCCU was acute severe hypertension unresponsive to oral medication or boluses of intravenous agents in the labour ward. This topic will be discussed in greater detail in Chapter 5.

Another common pre-eclampsia related complication requiring critical care support was respiratory distress secondary to pulmonary oedema (Table 6). The single most important intervention in the “After OCCU” group was early CPAP for pulmonary oedema. Four patients in the “Before OCCU” group required emergency intubation, three of these patients were transferred to the general ICU and one died in the labour ward. Only one patient in the “After OCCU” group required elective intubation and ventilation for pulmonary oedema and this case was also complicated by tuberculosis and pneumonia. Respiratory support in hypertensive disorders in pregnancy will be further discussed in Chapter 5.

4.6.10 Management of HIV

Sepsis was the third most common cause for admission in our study. Seven patients in the “Before OCCU” group and 6 patients in the “After OCCU” group (Table 7) had multiple organ dysfunction syndrome which has a high mortality rate (Mireno, 2007). In South Africa the number of pregnant women diagnosed with HIV has shown a steady increase with a concomitant rise in non-pregnancy related infections. This has been shown to increase the rate of maternal mortality (Saving Mothers 2005-2007). In the “After OCCU” group there were significantly more cases with HIV/AIDS yet the mortality amongst these women was significantly lower due to the support of the OCCU. During the early stages of the HIV pandemic surgical and medical ICU’s were reluctant to accept patients with AIDS and pneumonia or TB as their prognoses were regarded as very poor and treatment probably futile. During the index study critically ill patients were first resuscitated and sometimes ventilated before the full extent of their condition was appreciated. Although the numbers are small, the addition of critical care support for these patients allowed all except one to be discharged alive and stable. The importance of critical care support for pregnant women with sepsis will be discussed further in Chapter 5.

4.6.11 Obstetric haemorrhage

During the study period obstetric haemorrhage was one of the common causes of obstetric deaths in South Africa (Saving Mothers, 2011). Obstetric haemorrhage was common in both the “Before OCCU” and “After OCCU” groups (Table 4). All OCCU patients were managed using goal-directed resuscitation which included appropriate fluid and blood product administration, ongoing vital observations and invasive monitoring (Marino, 2007; Langenegger & Rout, 2010). Significantly more patients in the “Before OCCU” group developed new onset (after admission) severe haemorrhagic shock (table 13). This illustrates the importance and implementation of a major obstetric haemorrhage protocol and management in a critical care unit. Obstetric haemorrhage is a common primary cause for SAMM and maternal mortality and there are often preventable factors in both developed and developing countries (Ronsmans, 2006; Sultan et al., 2013; Tuncalp et al., 2012). This study demonstrated that by using goal-directed resuscitation for severe haemorrhage the incidence of advanced shock after admission to Tygerberg OCCU vs Tygerberg labour ward can be decreased (Table 15).

4.6.12 Effect of an Obstetric Critical Care Unit on hospital stay

The median hospital stay in the "After OCCU" group was longer (Table 12). Three factors could explain this difference. Firstly, the numbers are small. Secondly, more patients died in the "Before OCCU" group soon after admission which influenced the overall median hospital stay in both groups. Thirdly, non-consultant/resident level doctors cared for patients discharged from the OCCU and often kept these patients admitted for longer than necessary due to the preceeding morbidity.

The documented labour ward stay was shorter in the "After OCCU" group probably due to the fact that they were managed in OCCU as opposed to the labour ward. OCCU admission days were not recorded as labour ward admission days. Patients discharged from critical care units must have a detailed plan of management for the immediate step-down period which helps facilitate a shorter pre-discharge period. Early recognition and early intervention, even in the antenatal and labour phases, should decrease both OCCU, general ICU and hospital stay leading to cost savings.

4.6.13 Effect of an Obstetric Critical Care Unit on perinatal outcomes

Although the establishment of the OCCU significantly improved, maternal outcomes, including maternal mortality, no significant differences in perinatal outcomes were demonstrated for cases managed in the labour ward or in the OCCU. Some patients in the "After OCCU" group were however only transferred to the OCCU postnatally thereby excluding the opportunity to perform antenatal interventions to the benefit of the foetus. Generally speaking the critically ill mother is first stabilised before the foetus is monitored as maternal resuscitation goals take priority. However, effective maternal resuscitation will also benefit the foetus. It is important to take the foetal environment in the critically ill patient into account when resuscitating or when providing supportive care. For example, a maternal pH below 7.3 may affect the foetus adversely influencing its ability to oxygenate or maintain a normal acid base status. (Garite, 2004). The findings in this study reflect high perinatal losses in both groups. In a systematic review the overall perinatal mortality rate of obstetric patients admitted to general ICU's was 25.6% (Ananth & Smulian, 2010). The higher perinatal mortality rate of pregnant patients admitted for critical care may be due to the severity of illness, eg including poor organ perfusion acidosis hypoxia, initial management focussed on the mother and the higher incidence of severe prematurity and growth restriction such as pre-eclampsia.

The median gestational age at delivery fell in the late preterm period for both groups, being 35 weeks in the "Before OCCU" group and 34 weeks in the "After OCCU" group (Table 25). This may be due to the fact that the leading cause for admissions was pre-eclampsia which necessitated earlier delivery. The incidence of caesarean section was high in both groups, being 58% in the "Before OCCU" group and 60% in the "After OCCU" group. This may be due to the fact that many pre-eclamptic and other critically ill patients will undergo a caesarean section or induction of labour. Caesarean sections were performed for obstetric indications which included foetal distress and unsuccessful induction of labour. There were ten cases in total where specific caesarean section data were not available as these patients were transferred postnatally from other hospitals, however this small amount of missing data did not affect the over-all results. In antenatal patients who are critically ill, clinicians working in the general ICU (non-obstetric personnel) often request earlier delivery. This may be due to a variety or combination of reasons such as: limited availability of foetal monitoring and delivery infrastructure, lack of obstetric knowledge and skills as well as the fact that postpartum management is often simpler in specific cases. For these reasons it has been demonstrated that pregnant patients admitted to a general ICU have a greater chance of caesarean section (ACOG, 2009). In both the "Before OCCU" and "After OCCU" groups unstable neonates were transferred for high dependency or neonatal intensive care as indicated. Again there were no significant differences between the two groups.

No randomised controlled trials were identified that compared patients admitted to an OCCU as opposed to a normal labour ward. This study therefore makes a valuable contribution to the literature and demonstrates that the outcomes of critically ill patients can be improved by establishing an OCCU situated in a labour ward compared to providing care for obstetric patients with organ dysfunction or failure in the labour ward of a South African academic hospital. It will be important to study the medium and longterm outcomes of patients admitted to the Tygerberg OCCU. Such a case series report would add further support to the impact of an OCCU.

4.7 Conclusion

The MDG 5 to reduce maternal deaths in South Africa by 2015 is unlikely to be reached. Over the past 14 years the local maternal mortality rate has increased three fold (Theron, 2012). The proposed WHO basic and comprehensive EmOC and a comprehensive HIV management programme have been implemented in South Africa without having the desired effect on maternal mortality.

This study demonstrated a significant decrease in maternal mortality and morbidity in obstetric critically ill patients managed in a dedicated level 2/3 OCCU compared to a level 2/3 labour ward. The most important difference in the management of patients in the “Before OCCU” and “After OCCU” groups was the ability to transfer patients to an adjacent, dedicated unit with a specified operational model. This unit had appropriately trained staff with advanced monitoring to facilitate expeditious and appropriate interventions. In both this study and the Saving Mothers Report of 2008-2010 it was apparent that lack of critical care resources is an important preventable cause of maternal deaths. The ability of an OCCU unit (level 2) to upgrade to level 3 critical care when necessary saves maternal lives.

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CHAPTER 5: MANAGEMENT AND OUTCOME OF THE FIRST 302 PATIENTS ADMITTED TO A NEW OBSTETRIC CRITICAL CARE UNIT WITHIN THE LABOUR WARD: A PROSPECTIVE CASE SERIES

5.1 Context of the study

"Every woman who becomes pregnant and continues with her pregnancy does so in the expectation of delivering a healthy child and the joy and satisfaction of watching the child grow to maturity. Surely it is the duty of society and the health care profession, in particular, to do the utmost to fulfill this expectation?" (Saving Mothers; 2002). South Africa together with other member states signed the Millennium Development Declaration in 2000; whereby one of the main goals stated was to "decrease the maternal mortality ratio by three quarters" (MDG SA). The Confidential Enquiries reports resulted in the cooperation of government, clinicians, and midwives to compile national guidelines for obstetric management and essential steps in managing common causes of maternal deaths. Some of the achievements during 2005 were: free maternal and child healthcare; 90% of pregnant women accessed antenatal care and 91% of deliveries were conducted by a health worker (DHS, 2003); HIV counseling and testing and then management were offered. Obstetric patients were stratified according to risk at booking or later complications to receive care at a midwife obstetric unit, district hospital, regional referral hospital or tertiary academic hospital. However, despite the good intentions and planning, the figures show that maternal mortality rose after 1990 increasing every triennium (up to the 5th report). This in contrast to the planned 75% reduction in maternal deaths by 2015. The failure to decrease maternal mortality was also true for other African countries. According to a report by UNICEF: (A report card on maternal mortality, 2007), the MMR during the study period remained unacceptably high in sub-Saharan Africa (920 maternal deaths per 100 000 live births) and South East Asia (500/100 000) compared to a middle-income country such as Brazil (85/100 000) and a developed industrialised country such as the UK (8/100 000). The reasons for this must be investigated and solutions sought. Progress in reducing maternal deaths in SA and other African countries has been severely hampered by economic factors, poverty, HIV prevalence, extreme inequity and poor education especially with regard to healthy choices regarding family planning (Ronsmans & Graham, 2006).

The burden of disease due to HIV has increased both non-pregnancy-related and pregnancy sepsis-related deaths due to the impact of the virus on the immune system. A patient with HIV in South Africa has a 10-fold increased risk of mortality both from direct and indirect causes of death (Moodley & Moran, 2012). The reported SA, HIV specific mortality rate during the study period was reported to be 438 deaths /100 000 population. This is in sharp contrast to middle income countries such as Brazil where the cause-specific mortality due to HIV is only 8.4/100 000 (WHO 2014). The need for critical care support in the HIV obstetric group is essential especially during non-pregnancy-related infections and pregnancy-related infections which are treatable and reversible. Sadly non-pregnancy-related (NPR) infections increased from 768 (31.4% of total deaths) during 1999-2001 to 42% from 2002-2004. Substandard healthcare was associated with 40% of these deaths at level 2 regional and 22% of deaths at level 3 (tertiary) hospitals. Respiratory failure was the main final cause of death in 62% of the NPR infections cases and septic shock was the final cause of death in 9% of these cases (Saving Mothers, 2006).

In common with the global picture the frequent causes of maternal mortality were pre-eclampsia, haemorrhage, sepsis and complications of underlying medical diseases (Lancet, Ronsmans & Graham 2006). These direct and indirect conditions can rapidly lead to life-threatening critical illness. Geller et al. stressed the importance of identifying precipitating events that eventually lead to maternal death, which was described by him as "the last stop in the continuum of adverse events". This continuum includes the following events: normal/healthy pregnancy → morbidity → severe morbidity → near miss → death (Geller et al., 2004, Say et al., 2009). Obstetric patients may develop complications resulting in SAMM. Such patients then require more advanced care that cannot be provided in a standard labour ward.

In keeping with studies from other countries, the Confidential Enquiries into Maternal Death Reports in South Africa highlight insufficient critical care capacity and late recognition or sub-standard management and resuscitation of critically ill patients. The focus needs to be on effective affordable interventions to provide readily available, high quality, emergency management for these patients. The majority of research investigating admissions, management and outcomes for specialised support, critical care units is conducted in the realm of adult and paediatric general critical care. Similar criteria for research and management should hold true for critically ill obstetric patients. During the Tygerberg OCCU study period (2006) there was still no specific guidance on providing critical care to the obstetric population even in the United Kingdom and America. There were only a few case-series reporting on the impact of the establishment of obstetric critical care units within tertiary hospital labour wards. The studies will be summarised and later incorporated into the discussion section. In South Africa, Johanson et al. described their experience of admitting 258 high-risk antenatal and post-partum patients, into a three-bed obstetric critical care unit established during 1992-1993 within the labour ward of Groote Schuur Hospital, Cape Town (1995). The referral population was mainly of low socio-economic background and mixed racial and African origins. The study was performed prior to the impact of the HIV epidemic in South Africa. At that time the background institutional MMR in the Western Cape Province was reported to be only 34.6 per 100 000 deliveries (Theron, 1996). The main causes of critical illness were hypertension (60%), haemorrhage (18%) and medical disorders (22%). Non-pregnancy-related infections were very low at 6% (15 cases) and no HIV positive cases were reported. The unit was able to provide invasive haemodynamic monitoring and initial (though not prolonged) mechanical ventilation. Twenty-eight patients had to be transferred to the general intensive care unit for prolonged mechanical ventilation or level 3 general intensive care management. Seven out of the 258 admissions died (Johanson et al., 1995). Within the South African context, this early unit demonstrated clearly that better outcomes amongst patients with severe obstetric complications could be achieved. Even though the example of this unit could have been followed in other tertiary centres in South Africa, this was not the case and in fact this unit was not even mentioned in the Saving Mothers Report. Thus this pioneer unit remained alone in South Africa up to 2006.

In Memphis, Tennessee, Mabie and Sibai described a case series of 200 patients who were admitted to a tertiary referral (academic) Women's Hospital from 1986-1989 (1990). The background MMR in USA was estimated by the WHO to be 12/100 000 during 1990 (WHO 2014). This OCCU was able to provide level 2 and selected level 3 (two organ systems failing, invasive ventilation) critical care. Once again this unit was able to provide invasive haemodynamic monitoring and short-term mechanical ventilation. The main indications for OCCU admission were complications of pre-eclampsia (46%), massive haemorrhage (10%) and medical disorders (44%). Only nine patients needed transfer to general ICU for prolonged ventilation. There were seven deaths in this series.

Level 2 critical care is an essential pillar of critical care. Level 2 critical care knowledge, skills and on-site capacity lead to early recognition and intervention that often prevents further complications. Ryan et al described a case series of 123 critically ill obstetric patients admitted to a high dependency care unit (OCCU level 2) located within a regional obstetric center in Dublin, Ireland, over a period of four years (1996-1998). Only 18 patients (18/123) were admitted prior to delivery. The primary causes for admission were obstetric related in 100 cases (81.3%) and non-obstetric related in 23 patients (18.7%). Pre-eclampsia was the main indication for admission to the unit in 55 cases (44.7%). This institution operated with a two-tiered referral system. Certain patients were sent directly to the general ICU while others were transferred to the OCCU based on level 2 and 3 critical care requirements. Five patients were transferred to the general ICU and no maternal mortality was reported for the entire group (2000). This indicates appropriate selection according to available levels of care within an institution with sufficient capacity which certainly differs from the South African context.

Following the Ryan report, Zeeman et al., described their experiences of managing critically ill obstetric patients in the Academic Dallas County District Hospital, Texas (2003). They reported a two year post-establishment audit of a five-bed "intermediate care" unit (OCCU level 2) that included 483 women. Eighty percent of the patients were admitted post-partum. The indications for admission were obstetric in 318 patients (66%) and included 207 severe complications of pre-eclampsia, 85 cases of haemorrhage and four cases of puerperal sepsis. Infective medical causes included 12 cases of pyelonephritis and ten with pneumonia. No cases of tuberculosis or HIV were reported. The hospital's labour ward had an available two-tiered system in place that allowed for direct admission to ICU from the labour ward or theatres and then referral to the intermediate care unit. The main indication for ICU from either the labour ward, theatre or the OCCU was for ventilatory support (n=24). It was necessary to transfer 13 OCCU patients to the general ICU for level 3 critical care management. Only one patient in this case series died. This unit was valuable as it allowed for decreased ICU referrals as well as early step down care for obstetric patients from the ICU.

The lessons learned from these publications were not necessarily applicable to the need in the Tygerberg Academic Hospital labour ward as these OCCU's except for the Cape Town study were in first world settings and the Cape Town study was performed prior to the HIV pandemic and mass migration to the Cape Town Metropole from a large populous adjacent province. The levels of critical care provided to patients in the Zeeman and Ryan reports only involved level 2 obstetric critical care. Patients at risk of or requiring level 3 critical care were managed in general ICU's with sufficient available capacity. Establishing an exclusive level 2 critical care unit in Tygerberg Academic Hospital would probably have prevented further deterioration in patients with SAMM. However, if these patients needed level 3 care there would have been no guarantee of transfer to the general ICU. Twenty percent of the maternal mortalities in the previous South African triennial report died because there were no ICU bed's available at the time of the emergencies (Saving Mothers, 2012). The past and current severe shortages of critical care facilities in South Africa have been described in Chapter 4. The two earlier OCCU case series reports by Mabie and Sebai (1990) and by Johanson et al. (1995) in Cape Town, provide important guidance as both these units were able to provide both level 2 and level 3 care including short term ventilation. Units such as these would clearly facilitate quality management of critically ill patients in the labour ward of Tygerberg Academic Hospital.

Having described the local need for an obstetric critical care unit, the practical establishment thereof and a limited audit of the pre- and post-establishment phases. It was necessary to evaluate the performance of the unit over a longer period of time, thus involving a greater number of cases.

5.2 Hypothesis

Through the establishment and efficient use of an OCCU the maternal mortality and morbidity in critically ill obstetric patients can be decreased.

5.3 Objective

To describe the management and outcomes of a large cohort of critically ill obstetric patients managed in a newly established dedicated level 2/3 OCCU.

5.4 Methods

The study was performed in the labour ward at Tygerberg Academic Hospital. This hospital serves as both a secondary (specialist care) and a tertiary (sub-specialist care) referral unit. Tygerberg and Groote Schuur Hospitals are the only tertiary hospitals for adults in the Western Cape Province of South Africa. The number of deliveries performed in the entire Tygerberg Academic Hospital referral region during 2005 was 35 506. The number of deliveries performed in Tygerberg Academic Hospital during the same year was 7 489. This study population comprised mainly women of mixed race or African origin, mostly of low socio-economic status.

The OCCU was established using the detailed Tygerberg Academic Hospital OCCU Blueprint described in Chapter 3.

Specific criteria for the OCCU admission were detailed and communicated to all doctors working in the labour ward. The basic work-flow pattern in the hospital was as follows: all in-hospital or referred from out-of-hospital obstetric patients were transferred to the obstetric admission area, from where they were admitted to the labour ward. Patients who developed critical complications in the labour ward or in the operating theatre were transferred directly to the OCCU for level 2 critical care. The more serious cases would have ideally been transferred to the general intensive care unit but when no beds were available those patients were managed, at least initially, in the OCCU. Patients with acute collapse in the labour ward, were immediately transferred to the OCCU for resuscitation.

On admission to the OCCU the patient's details were recorded in an official admission record by the nursing staff. The duty doctors assigned to work in the OCCU, performed daily clinical assessments of the patients, recording all findings including monitoring and laboratory data as well as any special medical procedures or interventions performed in the OCCU. Based on all antenatal OCCU, and other clinical notes a specific audit sheet was then completed and entered into the database. Patient details continued to be recorded on the follow-up section of the data sheet for up to 42 days after delivery. The audit was done by a specialist obstetrician, but if he/she was not available, the audit was completed by a senior registrar and this was reviewed later by the original specialist obstetrician. A research midwife was employed to follow-up OCCU patients and babies for up to 42 days post- discharge from the OCCU, ICU or postnatal wards. This data was recorded to follow the outcomes of the study patients and to detect late complications, such as renal failure, thrombo-embolism, infections, and re-admission to hospital of mother or baby after discharge home. Any deaths were also recorded. All maternal deaths in South Africa are notifiable by law. The author was in charge of the process of morbidity and mortality review at departmental level as well as submitting this information to the NCCEMD.

During the official audit period, all data was collected according to the same methodology. Inclusion criteria for patients requiring care in the OCCU or general ICU were: antenatal, intra-partum and post-partum women with impending, developing or established organ dysfunction that could lead to long-term morbidity or death. This included patients with the following requirements: invasive haemodynamic monitoring, non-invasive respiratory support (CPAP support or non-invasive mask ventilation), emergency invasive ventilation where no general adult ICU bed was available and general ICU step-down care. More detailed indications for obstetric critical care are described in Chapter 3 and in Appendix 1 of Chapter 3. Exclusion criteria were: non-obstetric patients and patients with early pregnancy complications (<20 weeks' gestation) such as miscarriage or ectopic pregnancies (these patients were admitted to the general surgical ICU as per hospital policy), and futile care for example, brain death on arrival [DOH (SA), 2007].

The OCCU in Tygerberg Academic Hospital was established in March 2006. During the study period the APACHE score for each admission was calculated and recorded. To generate an APACHE score 12 clinical parameters are used and the most abnormal measure is recorded in the first 24 hours of the admission. Additional points are assigned to patients above 44 with severe underlying chronic health conditions such as chronic organ failure, or immune compromise (AIDS is included in this group) (Knaus, 1985). The SOFA score was also calculated and recorded. This score was designed to evaluate the function of the six major organ systems (Ferreira et al., 2001).

The equipment, staffing and functioning of the OCCU have been carefully described in Chapters 3 and 4. Definitions for organ complications and dysfunction are described in Chapter 4.

The primary outcome measures for this study were:

- Maternal mortality
- Major morbidity of patients after admission

Secondary outcome measures were:

- Quantify the need for obstetric critical care
- Determine the ability of the OCCU to provide the necessary organ support
- Clinical scoring systems to indicate severity of disease and outcome
- Levels of monitoring required and received
- Complications during clinical management
- Duration of admission to OCCU or general ICU
- Critical neonatal outcomes

Data were analysed by the Statistics Department of the University of Stellenbosch. Analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 10. Ethical permission was obtained from the Ethics Committee of Stellenbosch University (NO7/05/112). Anonymity of data was maintained by assigning a specific number to each patient after data collection and the Ethics Committee allowed for a waiver of consent.

5.5 Results

Data of patients admitted to the OCCU was collected prospectively from the opening of the unit on 1 March 2006 until 31 May 2007. During this study period there were 9 803 deliveries in the labour ward at Tygerberg Academic Hospital. During the 2005-2007 triennium, the NCCEMD reported the South African institutional MMR to be 152/100 000 deliveries (Saving Mothers, 2008). Tygerberg Academic Hospital is the tertiary referral centre for two regional and several district hospitals as well as Midwife Obstetric Units in the Western Cape. The OCCU also admitted patients from obstetric theatres and from the general intensive care units for step-down care. During the study period, 302 patients who had an indication for obstetric critical care management (138 antenatal and 164 postnatal) and who met criteria for obstetric level 2 or level 3 critical care were admitted to the OCCU. The widely used APACHE and SOFA clinical scoring systems were calculated as recommended by critical care societies across the world, to assess the severity of illness of patients managed in OCCU.

The maternal baseline characteristics are shown in Table 1.

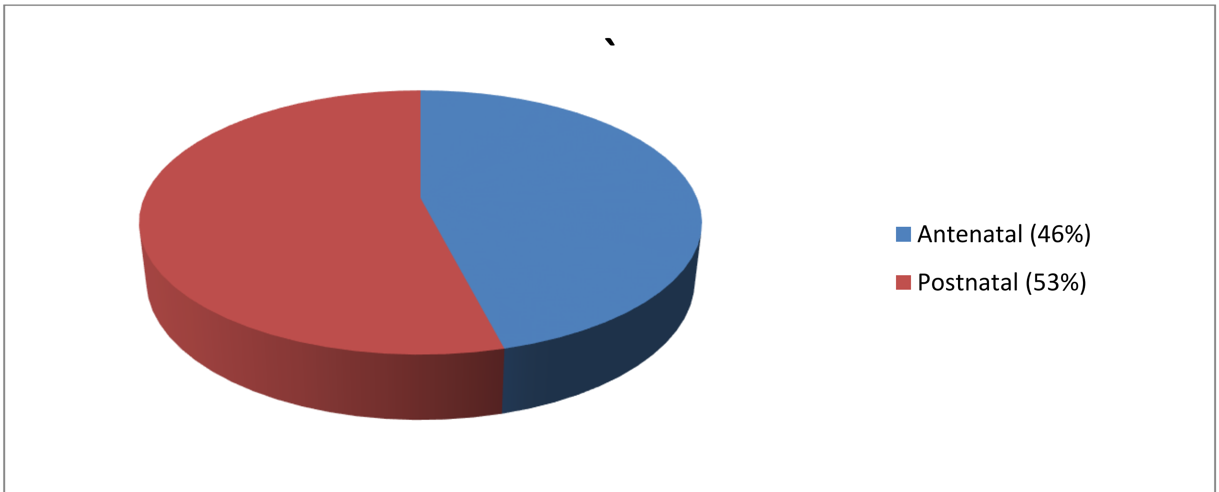
Table 1: Maternal baseline characteristics on admission to the Obstetric Critical Care Unit

	OCCU n = 302	Median	Range
Age		27	15-47
Gravidity		2	1-8
Parity		2	0-7
Caesarean sections	181 (59.9%)^		
Postnatal	164 (54.3%)^		
Antenatal	138 (45.7%)		
HIV*	62 (20.5%)		
AIDS*	25 (8.3%)		
Gestation at admission (weeks)		34	20-42
APACHE+ score (all emergency admissions)		11	6-39
APACHE+ score (level 3 care; n=104)		13	6-39
APACHE score (including elective and step down cases)		8	0-39
SOFA^ score (all emergency admissions)		3	0-16
SOFA score (level 3 care; n=104)		5	1-16

**HIV/AIDS = Human immunodeficiency virus infection/ acquired immune deficiency syndrome +acute physiology age chronic health evaluation. ^ SOFA score= Sequential Organ Failure Assessment*

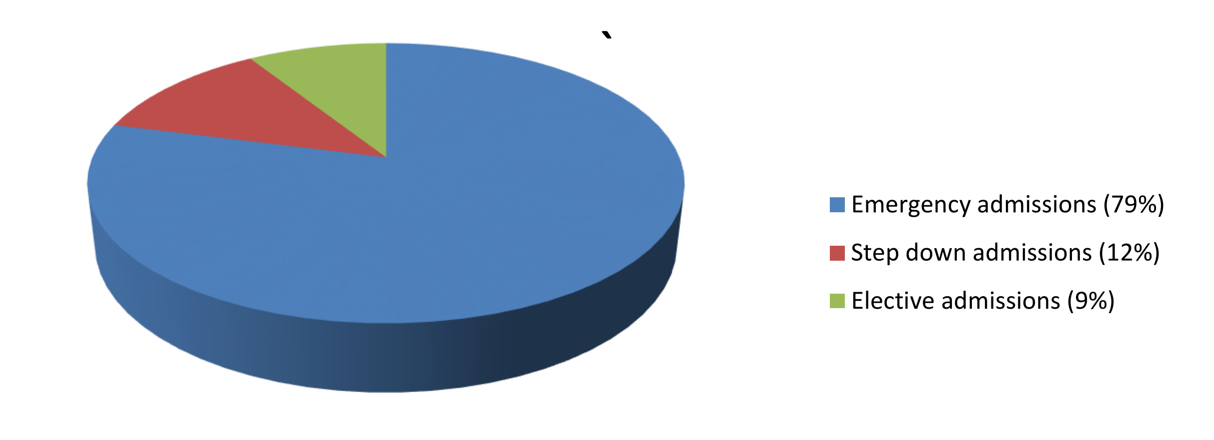
Figure 1 demonstrates the distribution of antenatal and postnatal admissions.

Figure 1: Distribution of ante- and postnatal Obstetric Critical Care Unit admissions



Thirty-five patients were transferred to the OCCU for step down care after management in the general ICU. It was only possible to accept 26 elective patients with high risk comorbidities such as cardiac disorders prior to planned delivery as illustrated in Figure 2.

Figure 2: Origin of referrals to the Obstetric Critical Care Unit



The classification of levels of critical care required and provided was documented. The initial aim was to admit level 2 patients and provide emergency short term level 3 care when necessary, and then transfer patients to the general ICU as soon as possible depending on ICU bed availability as well as the triage system of the general intensive care units. Nineteen cases admitted to the OCCU were later transferred either directly to the general ICU or via the operating theatre to the general ICU. The level of care and the time intervals of care provided in the OCCU are illustrated in Table 2.

Table 2: Level, and time intervals of critical care provided by the Obstetric Critical Care Unit

Level of critical care	**n = 302**	**%**
Level 2	198	65.6
Level 3	104	34.4
Level 3 care solely provided in the OCCU	38	12.6
Level 3 critical care in the OCCU then transferred to the ICU within 6 to 12 hours	34	11.3
Level 3 critical care in the OCCU then transferred to the ICU after 12 to 72 hours	32	10.6

5.5.1 *Admission indications*

Patients were classified in terms of the dysfunction of various organ systems. The organ system-based dysfunction or risk is listed in Table 3. Patients may have had more than one organ dysfunction.

Table 3: Indications for Obstetric Critical Care Unit admission based on organ system dysfunction

Organ system-based criteria	**OCCU n = 302**	**%**
Hypertension	168	55.6
Pulmonary	115	38.1
Cardiac	64	21.2
Severe sepsis[#]	57	18.9
Haemorrhage	53	17.5
Renal[+]	46	15.2
Neurological	28	9.3
Abdominal and or pelvic surgical complication	25	8.3
Metabolic/endocrine	20	6.2
Anaesthetic complication	7	2.3
Other	10	3.3

Patients may have more than one organ dysfunction, [+]Increase in serum creatinine × 2 and/or urinary output < 0.5 ml/kg/h × 12 hours or acute renal failure = Increase in serum creatinine ×3 and/or urinary output < 0.3ml/kg/h × 24 hours or anuria for 12 hours (Gammill & Jeyabalan, 2005; Bellomo, 2005); [#]Sepsis and organ dysfunction

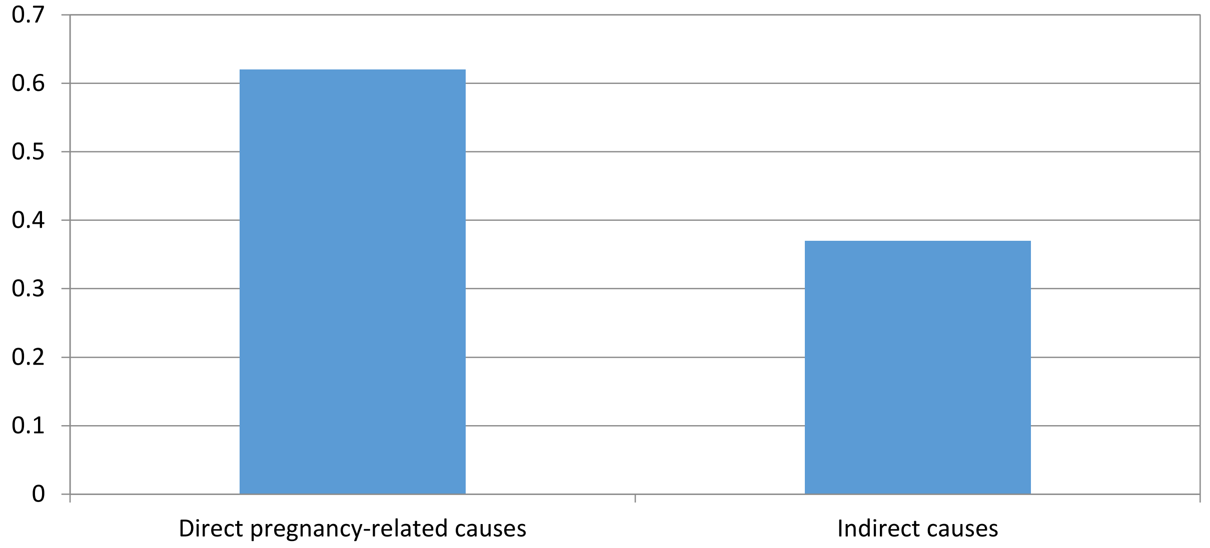
The primary cause for admission of each patient was recorded and classified according to the obstetric classification system from the South African triennial maternal mortality reports (Saving Mothers, 2006) (Table 4). There were more direct pregnancy-related causes (183; 61%) for admission compared to indirect causes (119; 39%) for admission to the OCCU as illustrated in Figure 3.

Table 4: Initial primary cause that led to Obstetric Critical Care Unit admission

	n = 302	**%**
Hypertensive disorders	131	43.4
Pre-existing medical or surgical disorders[#]	68	22.5
Severe non-pregnancy-related sepsis	35	11.6
Obstetric haemorrhage	33	10.9
Severe pregnancy related sepsis	22	7.3
Pulmonary embolism	10	3.3
Anaesthetic related	3	0.9

[#]medical disorders were predominantly cardiac disorders

Figure 3: Comparison of the percentage of direct and indirect causes for Obstetric Critical Care Unit admission



Pre-eclampsia was the most common cause of SAMM and admission to the OCCU. In addition some patients had another primary cause for admission where severe pre-eclampsia was also present. The profile of complications in pre-eclampsia and comorbidities is described in Table 5.

Table 5: Pre-eclampsia as primary or secondary cause of admission

	n = 168	**%**
SAMM (WHO) criteria	142	84.5
SAMM (Mantel et al., 1998)	118	70.2
Severe resistant hypertension[#] requiring continuous intravenous medication	137	81.5
Renal injury[+]	73	43.5
HELLP syndrome[Δ]	65	38.7
Pulmonary oedema[$]	56	33.3
Eclampsia – recurrent convulsions ± encephalopathy	40	23.8
Acute renal failure[++]	35	20.8
Severe haemorrhage (>5 units blood transfused)	29	17.3
Encephalopathy (unrelated to eclampsia)	16	9.5
Left ventricular failure	15	8.9
Coma[@]	6	3.6
Dialysis required on admission	4	2.4
Intracerebral haemorrhage	2	1.2

Patients may have more than one complication.
SAMM = severe acute maternal morbidity, [#]Systolic blood pressure >160mmHg and/or diastolic blood pressure >110mmHg, [+]Increase in serum creatinine × 2 and/or Urinary output < 0.5 ml/kg/h × 12 hours, [Δ]Haemolysis, elevated liver enzymes and low platelets, [$]Diagnosed clinically and radiologically, [++]Acute renal failure= Increase in serum creatinine ×3 and or urinary output < 0.3ml/kg/h × 24 hours or anuria for 12 hours (Gammill & Jeyabalan, 2005), [@]as defined by Mantel et al., 1998

Acute renal failure in patients with pre-eclampsia on admission was often encountered (n=35). The factors associated with acute renal failure and pre-eclampsia are listed in Table 6.

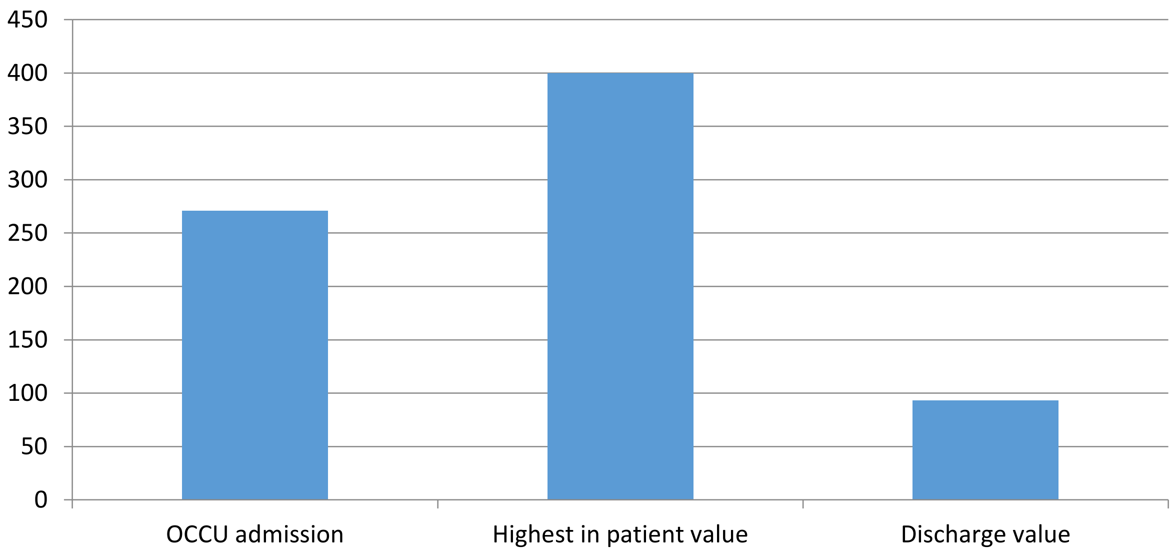
Table 6: Factors associated with acute renal failure and pre-eclampsia

Acute renal failure (ARF)* and pre-eclampsia	**n = 35**
HELLP+	26
SAMM haemorrhage^ (8 cases with placental abruption and intra-uterine death)	18
Pulmonary oedema	11
Anaesthetic-related hypotension	3

**increase in serum creatinine ×3 and or urinary output < 0.3ml/kg/h × 24 hours or anuria for 12 hours (Gammill & Jeyabalan, 2005), +Haemolysis, elevated liver enzymes and low platelets, ^more than 5 units of blood transfused*

The patients admitted with pre-eclampsia and renal failure had median creatinine levels of 271 (55-781) on admission, 400 (67-1891) for highest value during admission, and 93 (60-1891) µmol/l at discharge, as illustrated by Figure 4.

Figure 4: Median creatinine (µmol/l) in 35 patients with pre-eclampsia and renal failure



Acute renal failure = Increase in serum creatinine ×3 and or urinary output < 0.3ml/kg/h × 24 hours or anuria for 12 hours (Gammill & Jeyabalan, 2005; Bellomo, 2005)

Haemorrhage was one of the most common causes for OCCU admission and SAMM. Some of these patients had another organ-based admission criterion for admission. The profiles of 59 (20%) patients with severe haemorrhage are described in Table 7.

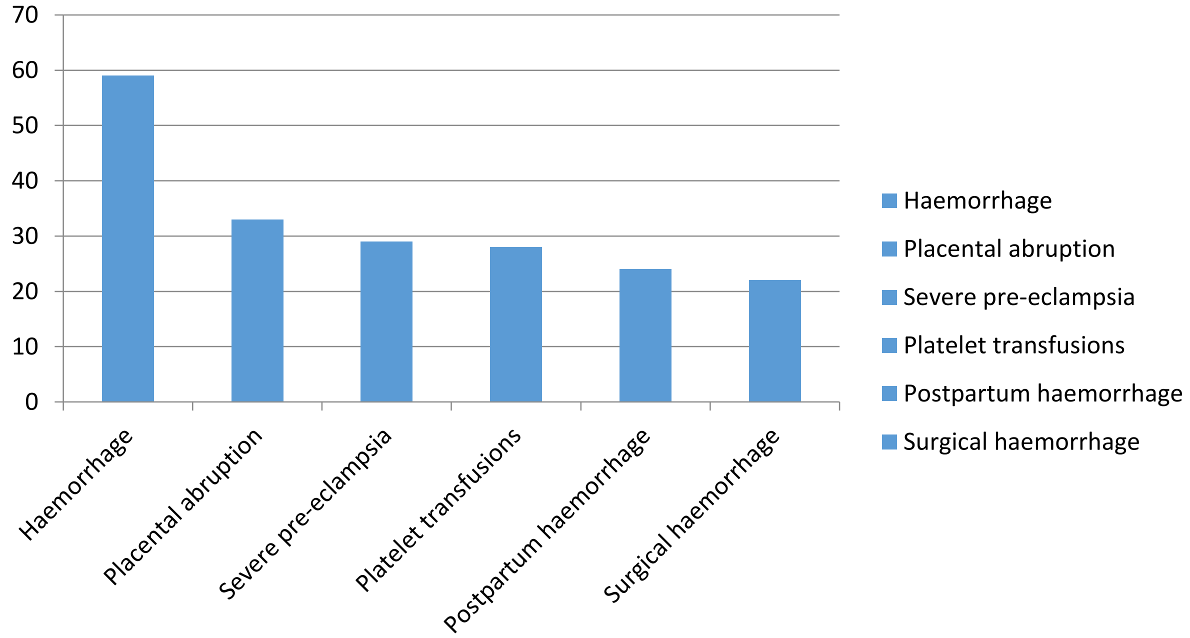
Table 7: Patients with severe haemorrhage* and comorbidity

	n = 59	% of haemorrhage group	% of OCCU patients
Placental abruption: total	33	55.9	10.9
Placental abruption and live fetus	12	20.3	3.9
Placental abruption and dead fetus	21	35.6	6.9
Severe pre-eclampsia	29	49.2	9.6
Platelet transfusion	28	47.5	9.3
Surgical haemorrhage during caesarean section	22	37.3	7.3
HELLP#	21	35.6	6.9
Acute renal failure^ (1 case of dialysis)	18	30.5	5.9
Clotting abnormality	16	27.1	5.3
Hysterectomy for haemorrhage	12	20.3	3.9

**meets SAMM criteria for haemorrhage according to Mantel et al., 1998 which results in vascular dysfunction with hypovolaemia and >5u blood transfusion (massive blood transfusion) and/or hysterectomy for haemorrhage, #Haemolysis, elevated liver enzymes and low platelets, ^ increase in serum creatinine ×3 and or urinary output < 0.3ml/kg/h × 24 hours or anuria for 12 hours (Gammill & Jeyabalan, 2005)*

Figure 5 illustrates the profiles and comorbidities of patients who experienced severe haemorrhage.

Figure 5: Patients with severe haemorrhage* and comorbidity



**meets SAMM criteria for haemorrhage according to Mantel et al., 1998 which results in vascular dysfunction with hypovolaemia and >5u blood transfusion (massive blood transfusion) and/or hysterectomy for haemorrhage*

5.5.2 Severe acute maternal morbidity on admission

In order to identify risk and better evaluate maternal care, all patients were assessed for SAMM criteria according to the South African study by Mantel et al., using organ and management based criteria (1998). These data are shown in Table 8, while Table 9 lists the primary causes of SAMM. It is important to note that 50 of the 198 (25%) cases of SAMM according to the "Mantel" criteria were HIV positive. Eleven percent of these SAMM cases met AIDS criteria (WHO Stage 4 disease).

Table 8: Severe acute maternal morbidity at Obstetric Critical Care Unit admission

	n	%
Total SAMM (Mantel et al.,1998)	198	65.6
Level 3 critical care management	104	34.4
Pulmonary oedema	66	33.3
Vascular dysfunction: hypovolaemia and >5u blood transfused	51	25.8
Respiratory dysfunction	50	25.3
Renal failure	46	23.2
Platelet transfusion	42	21.2
Immune system failure: level 3 critical care for sepsis	29	14.6
Hysterectomy for sepsis	16	8.1
Cerebral SAMM	12	6.1
Hysterectomy for haemorrhage	12	6.1
Cardiac arrest	10	5.1
Pulmonary embolus	10	5.1
Metabolic dysfunction	9	4.5
Liver failure	5	2.5
Pre-eclampsia and jaundice	5	2.5
Anaesthetic complication	3	1.5

Patients may have had more than one category of SAMM; note that the totals reflected here are strictly according to the "Mantel" criteria and may differ from previous tables.

The Tygerberg obstetric unit follows a conservative approach towards platelet transfusion. The indications for platelet transfusions during the study period were mainly peri-operative active bleeding with a platelet count below 50 000/mCL and a platelet count of below 10 000/mCL in patients with HELLP syndrome during the second stage of labour.

Using the NCCEMD classification system the primary causes for SAMM (Mantel classification) were reported.

Table 9: Primary causes of severe acute maternal mortality (Mantel et al., 1998)

	n = 198	**%**
Hypertensive disorders of pregnancy	80	40.4
Obstetric haemorrhage	30	15.2
Pre-existing medical disorders*	30	15.2
Severe non-pregnancy-related sepsis#	24	12.1
Severe pregnancy-related sepsis#	18	9.1
Embolism	10	5.1
Anaesthetic related	3	1.5
Other (2 X acute fatty liver, 1 X non-Hodgkins lymphoma)	3	1.5

**mainly cardiac; #sepsis and organ failure/dysfunction and/or septic shock*

After evaluation of all the OCCU cases for the SAMM criteria used by Mantel et al., 1998, the same data were evaluated using the WHO 2009 criteria. This latter system was available by the time of data analysis and is more comprehensive than the "Mantel" system. When the "Mantel" SAMM criteria were applied to the total OCCU group (n = 302), 198 cases of SAMM were identified. Thereafter the WHO 2009 SAMM criteria were applied to the remaining (302-198=104) cases and another 44 cases with SAMM were identified bringing the grand total to 242.

Table 10: System-based classification of severe acute maternal mortality according to WHO 2009 criteria in 104 cases not already classified with severe acute maternal mortality according to Mantel et al., 1998

System	**Criteria**	**n = 44**
Renal	Serum creatinine>300µmol/l; oligouria (<30 mls/hr for 4 hours) not responsive to fluid administration and diuretics; dialysis for ARF (other than pulmonary oedema)	15
Cardiac	Shock non responsive to fluids or vasoactive drugs, including adrenaline, dobutamine; hypo-perfusion; lactate>5mmol/l, pH<7.1	13
Neurological	Stroke, uncontrollable fits, status epilepticus, paralysis	10
Coagulation/ haematological	Failure to form clots, Platelet count <50 000/ml	7
Respiratory	Cyanosis; RR>40/breaths per minute	6
Hepatic	Total bilirubin >100µmol/l (pre-eclampsia excluded)	3

Results given as n = number of cases, the 44 patients had more than one category of SAMM

5.5.3 Interrogation of specific critical care support for various organ system failures

After classifying the various categories for SAMM, further details of the specific Level 3 management required are shown in Table 11, including other relevant or widely practiced clinical scoring systems by way of comparison.

Table 11: Organ system failure requiring level 3 critical care support

Organ system failure	Level 3 OCCU care followed by general ICU care within 48 hours	Exclusive level 3 OCCU care
N	66 (63.5%)	38 (36.5%)
Circulatory shock	17	9
Cardiac failure	26	17
Encephalopathy / coma	8	4
Respiratory failure & mechanical ventilation	40	7
Non-invasive ventilation	7	14
Renal failure	10	14
Jaundice	2	2
Clotting failure	10	9
SAMM# (Mantel et al., 1998)	66	38
MODS$ (sepsis)	14	10
MOF* (any cause)	43	28
AIDS	10	6
HIV positive (not AIDS)	19	12
APACHE scores (median, range)	16 (4-39)	15 (8-37)

*All patients were ventilated for >24 hours and/or ≥2 organ system failures. #Severe acute maternal morbidity, $multi organ dysfunction system, *multi organ failure*

5.5.4 Management and monitoring in the Obstetric Critical Care Unit

One of the most basic initial functions of critical care management in the OCCU was to attend to special and continuous monitoring of patients' systems, with particular attention to the cardiovascular and respiratory organ systems. The monitoring and associated complications are shown in Table 12.

Table 12: Monitoring and associated complications in the Obstetric Critical Care Unit

Monitoring	**n = 302**	**%**
SaO_2 monitoring and ECG routine monitoring	302	100
Intra-arterial line (a-line)[&]	275	91.1
• Pre-eclampsia	160	
• Respiratory distress	88	
• Haemorrhage	53	
• Severe sepsis	47	
A-line complication: insertion site infection	2	0.7
Central venous line inserted (CV-line)[&]	199	65.9
• Pre-eclampsia & complication	135	
• Haemorrhagic shock	41	
• Severe sepsis	39	
CV-line complication: insertion site infection	3	1.5
CV-line complication: iatrogenic pulmonary oedema	2	1.0
CV-line complication: pneumothorax	1	0.5
Pulmonary artery catheter (PAC)	19	6.3
PAC complication: insertion site infection	2	10.5
PAC complication: arterial puncture sub-clavian artery	1	5.3
PAC complication: pneumothorax	1	5.3
PAC complication: supra-ventricular tachycardia	1	5.3

[&]more than one indication for monitoring intervention

The indications for the insertion of a central venous line and/or PAC in cases with pre-eclampsia are shown in Table 13, while Table 14 demonstrates the indications for all pulmonary artery catheter placements.

Table 13: Indications for central venous line and/or pulmonary artery catheter in cases with pre-eclampsia (n=135)

Indication	**Central venous line**	**%**	**Swan pulmonary artery catheter line**	**%**
Resistant oliguria	47	34.8	9	6.7
Oliguria and pulmonary oedema	25	18.5	8	5.9
Oliguria and haemorrhagic shock	21	15.6		
Oliguria and severe sepsis	8	5.9		
Other indications for central venous line: central venous saturation, rapid infusion of potassium, inoptropes and/or vasopressors	34	25.2	N/A	N/A

A patient can belong to more than one group

Table 14: All indications for pulmonary artery catheter placement

Indication for PAC	n = 19	%
Cardiac patient NYHA classes III, IV	8	42.1
Pre-eclampsia and resistant oliguria	5	26.3
Resistant pulmonary oedema	5	26.3
Unresponsive shock	1	5.3

**Patients may have more than one indication; NYHA*

Respiratory support was frequently indicated and initiated in the OCCU as indicated in Tables 15 and 16. Both non-invasive and invasive ventilation were available for respiratory support. The OCCU functions as the entry port for the majority of complicated obstetric referrals. This facilitates rapid acceptance and transfer to the tertiary unit. In this study some patients arrived from referral hospitals, already intubated and ventilated, others were admitted from the operating theatre, while others were intubated and then ventilated on arrival in the OCCU or during OCCU stay (Table 15). Invasive mechanical ventilation was necessary in 50 patients (17% of admissions). The primary indications for invasive ventilation are shown in Table 15.

Table 15: Invasive mechanical ventilation

Primary clinical indications	n = 50	16.6% (of total admissions)
Hypertensive disorder: Pulmonary oedema (n = 9) Neurological indication (n = 6)	15	30.0% (of ventilations)
Medical disorders	12	24.0% (of ventilations)
Non-pregnancy-related sepsis	11	22.0% (of ventilations)
Pregnancy related sepsis	8	16.0% (of ventilations)
Haemorrhage	2	4.0% (of ventilations)
Anaesthetic	2	4.0% (of ventilations)

Patients with respiratory failure in the OCCU who were not intubated were first assessed for suitability for CPAP (awake, could maintain the airway, likely reversible cause) and/or later non-invasive Bi-PAP. Both of the latter represent non-invasive forms of respiratory support with the aim of preventing intubation and associated complications as shown in Table 16.

Table 16: Non-invasive respiratory support: Continuous Positive Airway Pressure and Bi-level Positive Airway Pressure

Indication for respiratory support	CPAP	Bi-PAP	Progress to intubation	Intubation (%)
Pre-eclampsia and pulmonary oedema^	56	9	7	12.5
Pre-eclampsia and pulmonary oedema (only CPAP support)	49		2	4.1
Pneumonia (incl 8 cases with AIDS)	32	14	11	34.4
Cardiac related respiratory failure excl pre-eclampsia	13	3	4	30.8
Post-operative cases with obesity & pre-eclampsia & RR>28 breaths/min	13	0		0

Data only provided for most common CPAP indications, does not cover all CPAP cases. ^ 47 pre-eclampsia pulmonary oedema cases receiving CPAP only and 2 cases required intubation

5.5.5 Administration of intravenous vaso-active infusions

Administration of continuous intravenous infusions of vaso-active drugs was frequently necessary in the OCCU patients. Most often the need was for antihypertensive therapy but a significant number of patients also required inotropic support as shown in Table 17.

Table 17: Administration of intravenous vasoactive drugs in the Obstetric Critical Care Unit

	n = 302	%
Labetolol	117	38.7
Nitrates	42	13.9
Dihydralazine	38	12.6
Inotropes	34	11.3

Many patients required more than one agent

5.5.6 Dialysis for renal support

Four patients were admitted to the OCCU with established renal failure that required dialysis. The renal physicians determined the cases that required dialysis. These physicians placed the dialysis catheters and thereafter the haemo-filtration technologists carried out the prescribed dialysis. It was possible to provide initial dialysis in the OCCU whilst waiting for a general ICU bed. The role of the OCCU during dialysis would involve monitoring and blood transfusion when indicated. All of these patients were then transferred to the general ICU as shown in Table 18.

Table 18: Cases with renal failure requiring dialysis

	Background	s-Creatinine on admission (µmol/l)	s-Creatinine at discharge from hospital	Outcome at discharge from hospital
1	Initial condition: pre-eclampsia Anaesthetic: shock after spinal block for C/S* Respiratory failure OCCU admission	781	271	Acute renal failure resolved
2	Initial condition: pre-eclampsia C/S Massive haemorrhage	779	87	Acute renal failure resolved
3	Initial condition: pre-eclampsia C/S Pregnancy related sepsis/shock Hysterectomy	271	1615	Chronic renal failure#
4	Initial condition: pre-eclampsia C/S Massive postpartum haemorrhage Hysterectomy	187	87	Acute renal failure resolved

**caesarean section; #chronic renal failure according to Gammill & Jeyabalan, 2005; Bellomo 2005*

5.5.7 Maternal outcomes in terms of new morbidity or death after Obstetric Critical Care Unit admission

After the initial admission to the OCCU, further pre-defined critical incidents and/or complications were record recorded as shown in Table 19.

Table 19: Critical incidents and/or complications (excluding mortality) in the Obstetric Critical Care Unit

	N
Intubation	21
Haemorrhagic shock	8
Cardiac arrest	6
Catheter sepsis	6
Shock (septic, cardiogenic)	6
Nosocomial pneumonia	5
Encephalopathy	4
Aspiration	2
New onset pulmonary oedema	2
Pneumothorax	2
Pressure sore	2

Patients may have more than one incident

5.5.8 Transfer to the general Intensive Care Unit

The 66 transfers to the general ICU's within 24 hours of OCCU admission have already been shown in Table 2. Table 20 shows the indications for the transfer of these patients, while Table 21 illustrates the duration of admission to the various units.

Table 20: Indications for transfer of Obstetric Critical Care Unit patients to the general Intensive Care Units

	N	
Ventilation	40	
Renal failure	28	
Severe sepsis with >1 organ system failure	21	
Cardiovascular[#]	20	
Multi-organ dysfunction syndrome	15	
Septic shock	9	
Neurological[+]	7	
Acute respiratory distress syndrome	6	

Patients can have more than one indication for transfer [#] including valvular lesions, cardiac failure; [+]e.g. coma, brain oedema

Table 21: Duration of admission

	Median	Range
Total hospital admission (days)	8	(1-70)
OCCU admission	2	(1-15)
General ICU admission	3	(1-20)
OCCU admission for patients with an indication for a general ICU bed but where no bed was ever available	3	(1-20)

5.5.9 Maternal mortality in the study group

The numbers and localities of maternal deaths (patients who had been managed in the OCCU at any stage during pregnancy) are shown in Table 22. The total group of mortalities had SAMM criteria on admission. During the study period there were other maternal deaths, but these patients were not managed in the OCCU or labour ward and were therefore not recorded for the purpose of this study.

Table 22: Maternal mortality

Total mortality in 302 patients admitted to OCCU: Place and cause of death	8
Deaths in the OCCU	3
Pulmonary embolism	
Puerperal sepsis in HIV+ patient	
Non-pregnancy related sepsis with PCP pneumonia in patient with AIDS	
Deaths in the general ICU	4
Acute fatty liver in pregnancy	
Non-pregnancy related sepsis with tuberculosis pneumonia and AIDS	
Puerperal sepsis in HIV+ patient	
Stage 4 lymphoma and multi-organ failure	
Death in an obstetric ward	1
Pulmonary embolism after discharge from the OCCU in a patient with pre-eclampsia	

Numbers given as n

All patients with sepsis had HIV disease (n=4) and/or AIDS (n=2). Thus four of the eight deaths were in HIV+ (50%) women. Pre-eclampsia was the most common primary cause for admission, monitoring and intervention, however there was only one maternal death directly related to complications of this condition. Therefore in this series the mortality in severe pre-eclampsia was 1% and the SAMM:death ratio for patients with the initial problem of pre-eclampsia was 80:1 according to the Mantel et al. 1998 classification. Two patients died due to pulmonary embolism. The first case was admitted during the postnatal period with the diagnosis of pulmonary embolism. It is not known whether she received thrombo prophylaxis before OCCU admission. In the second case, the patient was initially admitted with pulmonary oedema, secondary to a mitral stenosis. She had a prolonged stay in the surgical ICU and was then discharged to the ward where she died as a result of the embolism. She received thrombo prophylaxis during her stay in the OCCU and ICU.

The clinical scoring systems used for the prediction of mortality in general ICU patients and other risk factors associated with death are described in Table 23 as well as Figure 6.

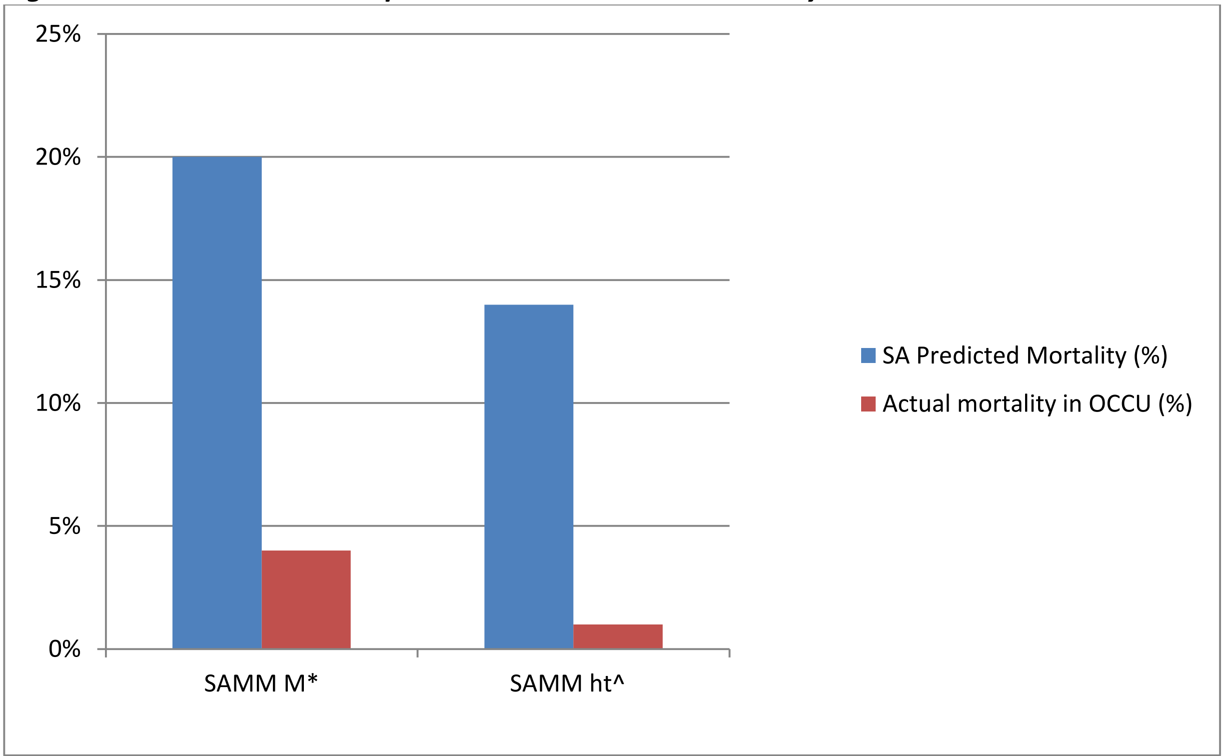
Table 23: The clinical scoring systems for predicting mortality and other mortality risk factors

	SOFA* (highest score) with predicted mortality (%)	APACHE II+ (score with predicted risk of mortality [%])	Multi-organ failure (number of failed organ systems)	Multiple organ dysfunction syndrome (sepsis)
Case 1	10 (46)	22 (40)	3	
Case 2	7 (18)	20 (40)	2	
Case 3	14 (86)	30 (71)	3	1
Case 4	16 (86)	29 (51)	3	1
Case 5	12 (86)	27 (51)	3	1
Case 6	10 (46)	27 (51)	3	
Case 7	15 (86)	28 (51)	3	1
Case 8	14 (86)	37 (82)	3	1
Median	12 (86)	27 (51)		
Range	7-15	20-37		
Mean	12.25	27.5		
Standard deviation	2.7	4.8		

**Sequential Organ Failure Assessment, +Acute Physiology Age Chronic Health Evaluation*

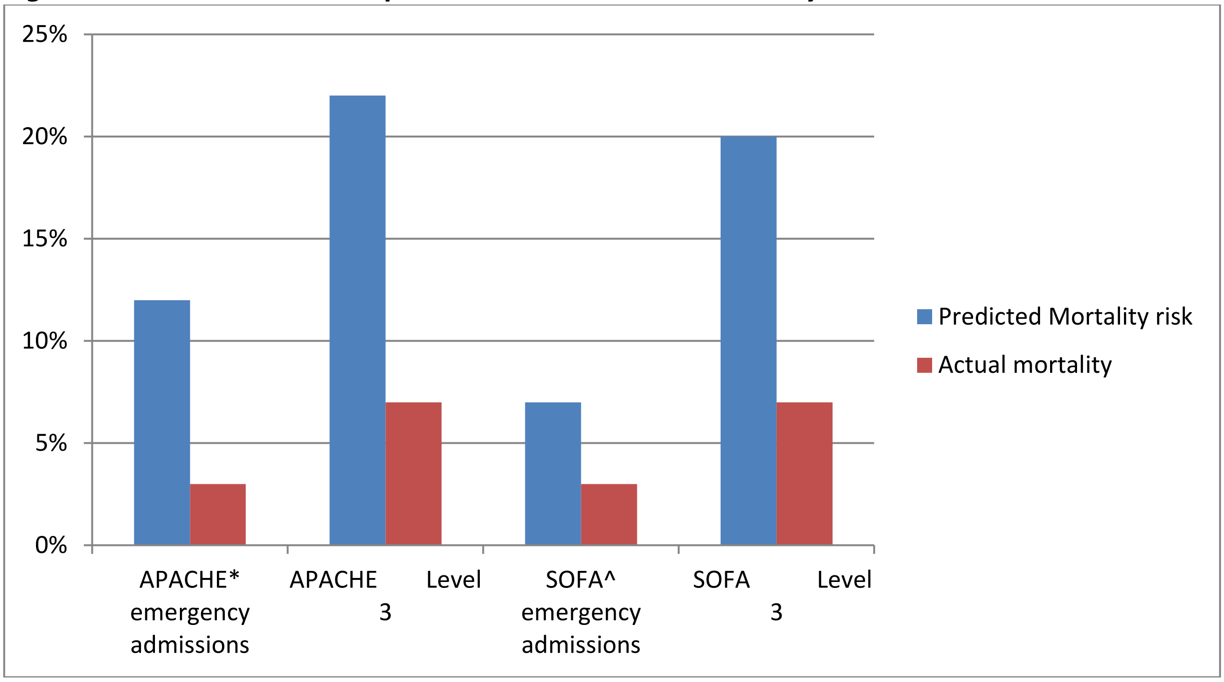
In Figure 6.1 and 6.2 comparisons are made between various clinical risk scoring systems for severe maternal morbidity and risk of mortality. Thresholds for the APACHE II and SOFA scores are compared with the predicted and actual mortality risks.

Figure 6.1: Risk markers and predicted versus actual mortality



SAMM M= Severe acute Morbidity (Mantel et al., 1998) South Africa*
SAMM ht^= SAMM in pre-eclampsia (Lombaard et al., 2005) South Africa

Figure 6.2: Risk markers and predicted versus actual mortality



*Data from Table: 1, (*Knaus et al.,1985); (^Ferreira et al.,2001)*

Further detail of the maternal deaths of women who had been managed at any stage in the OCCU are shown in Table 24 (note that the individual case numbers are consistent across Tables 23-24).

Table 24: Details of maternal mortality in cases who had received Obstetric Critical Care Unit care

Cases	Gestation at incident (weeks)	Ante-, or postnatal on admission to the OCCU	Primary cause of death	Final cause of death	Place of death
Case 1: 32-year old G3P3	30	Postnatal	Pulmonary embolism	Respiratory failure with circulatory failure, cardiac arrest	OCCU
Case 2: 26-year old G2P2	Unknown	Postnatal	Pulmonary embolism (pre-eclampsia, mitral stenosis)	Respiratory failure with circulatory failure	Ward (day 27)
Case 3: 22-year old G2P1	30	Antenatal	Pregnancy related sepsis HIV	MODS Septic shock Respiratory failure (pulmonary oedema, ARDS) renal, liver and haematological failure Immune system failure	MED ICU was d3 ICU
Case 4: 20-year old G1P0	30	Antenatal	Non-pregnancy related sepsis (TB, PCP) HIV stage IV	MODS Respiratory failure, Circulatory failure Renal failure Immune system failure	OCCU
Case 5: 23-year old G1P1	38	Postnatal	Pregnancy related sepsis HIV	MODS Circulatory Septic shock Respiratory failure ARDS Immune system failure	OCCU
*Case 6: 30-year old G2P2	31	Postnatal	Acute fatty liver	Hepatic failure Respiratory failure Renal failure Circulatory failure	General ICU
*Case 7: 26-year old G1P0	27	Antenatal	NPR Tuberculosis and pneumonia HIV	MODS Respiratory failure Circulatory failure Immune system failure	General ICU
Case 8: 25-year old G1P0	30	Antenatal	Burkitt's lymphoma stage IV	MODS Cardiac arrest on arrival	General ICU

** Case 6 and case 7 mortality during the "After OCCU" audit period in Chapter 4*

5.5.10 Neonatal data and outcomes

The neonates in the study group were delivered in the labour ward, OCCU or at a referring institution. The available neonatal data for the total study group is described in Table 25 while the outcomes of viable pregnancies admitted to the OCCU are shown in Table 26.

Table 25: Descriptive and delivery data of all fetuses/neonates in the study group

	N or mean*	Percentage or range*	Median	Standard deviation
Gestation (weeks) (n=279)	33.5*	20-42*	34	4.8
Weight (g) (n=247)	2142*	450-4720*	2100	1001
Induction of labour#	162	53.7		
Caesarean section	181	59.9		
Vaginal delivery	111	36.8		
Not delivered	10	3.3		

The gestation of patients admitted to or delivered in the OCCU was not always certain. In the same fashion the weight of babies delivered outside the institution was not always obtained.
#induction of labour in general labour wards or OCCU

Neonatal viability at Tygerberg Academic Hospital during the 2006-2007 period was set at 28 weeks gestation or 800g. The outcomes of the neonates of mothers that were admitted with viable pregnancies to the OCCU and who delivered during this period of care are described in Table 26. In 10 additional cases (not listed in the table below) patients were discharged after care in the OCCU (eg resolved pneumonia) for further management and delivery in other appropriate units.

Table 26: Outcome of viable pregnancies admitted to the Obstetric Critical Care Unit

Viable pregnancies on admission	**106**	**%**
5 min Apgar <7	8	7.5
Vaginal delivery	33*	31.1
Caesarean section	73	68.9
NICU* admission	11	10.4
High care admission (prematurity)	19	17.9
Neonatal death	8	7.5

In 4 cases (not included in the above table) delivery data were uncertain
**neonatal intensive care unit*

With regard to the neonatal deaths, four babies were delivered prematurely due to pre-eclampsia; three other pregnancies were complicated by both pre-eclampsia and placental abruption, while one baby was delivered prematurely due to maternal decompensation with severe mitral stenosis.

5.6 Discussion

5.6.1 Objective and primary outcome

Through the establishment of the Tygerberg Academic Hospital OCCU critically ill obstetric patients with existing or developing organ dysfunction and/or failure were admitted and managed. The unit was able to provide both level 2 and level 3 critical care. This study (Chapter 4) demonstrated a decrease in maternal mortality when comparing periods before and after the establishment of the OCCU (Langenegger et al., 2012b). These encouraging findings needed to be confirmed in a larger case series. In essence the study needed to demonstrate that these pregnant women had suffered severe complications and that through the provision of obstetric critical care morbidity and mortality rates remained low.

The results of Chapter 5 demonstrated exactly this. The severity of critical illness present in the OCCU population was high. This was indicated by the high incidence of SAMM as well as the admission profile using clinical risk scoring systems. However, the maternal mortality during the study period was 2.6%. Only eight patients of the 302 OCCU admissions died. Four of these patients died in the OCCU, three after transfer to the general ICU and one after discharge to the postnatal ward.

5.6.2 Clinical scoring calculations defining severity of critical illness and predicted outcome

The demonstration of low mortality rates and good outcomes compared to other reported series from critical care units must be done while adhering to standard clinical risk scoring systems. These systems usually demonstrate the severity of the disease and risk of death and are used for research purposes and prognosis. The APACHE II (Knaus et al., 1985) and the more recent SOFA scores (Ferreira et al., 2001) were utilised in this study. However, in the management and audit of a unit, these acute scores are not without drawbacks. For example, an elective admission to the OCCU of a woman with a serious chronic underlying disorder such as severe but stable mitral stenosis, requiring delivery will not reflect a severe APACHE II or SOFA score. The majority of the OCCU admissions were acute (Figure 2). For this reason the APACHE II median of the acute admissions was used to evaluate the severity (Table 1). Both the APACHE II and SOFA scores did indicate the degree of critical illness in these patients (Tables 1 & 11). Both systems predicted a mortality risk of around 7-20% for the all acute OCCU emergency admissions (levels 2 and 3), and around 22% mortality risk for level 3 patients (104/302 patients). These systems confirm the very high risk of death. In summary clinical risk scores are useful for predicting morbidity and death. The patients in Chapter 5 had high scores but with appropriate critical care management the mortality rates were low. All patients who died had high predictive scores. The scoring systems utilised are known to have limitations, particularly when applied to pregnant women where the APACHE II score may over predict risk of death (Lapinsky, et al. 2011). Several variables such as the specific underlying disease or the skill of a particular physician are able to modify a predicted outcome (Marino, 2007). The critical question to ask is whether these scores over predicted the risk of death or whether the critical care provided in the labour ward lowered the risk of mortality. While there is evidence to suggest that scoring systems may over predict, this data shows that the substantive contribution of the OCCU cannot be ignored.

Fatima Paruk developed a new pregnancy mortality risk stratification scoring system (GRAMPT) for obstetric patients admitted to the general ICU. A high score (>50%) indicates a high risk of death (Ngene et al., 2013). This risk stratification system should be further investigated.

Previously published obstetric critical care unit studies (as opposed to studies describing obstetric admissions to general intensive care units – see Chapter 2) did not report or calculate clinical risk scoring systems. A strength of the index study is that it reported both SOFA and APACHE II scores, thereby demonstrating adherence to critical care principles of data capture. In this way severity of illness was demonstrated and data could be compared the other available study populations.

The finding of lower than expected maternal mortality in the index study is supported by three large case series that reported on obstetric admissions to general critical care units. These studies are emphasised for the following reasons.

- Obstetric patients were admitted for both level 2 and level 3 care.
- These units had the capacity to admit antenatal patients.
- These studies reported clinical risk scoring systems and SAMM.

The first of these studies was performed in Brazil and reported a case series of 673 obstetric patients admitted over a five year period from 2002-2007, to a general ICU in a Women's Hospital (Oliveira Neto et al., 2009). The background MMR in Brazil was 58/100 000 at the time of the study (WHO, 2014). The available infrastructure was at the standard of a general ICU and the primary caregivers were board certified intensivists. Obstetricians were closely involved with the obstetric and surgical aspects of care. The main causes for admission were hypertensive disorders 324 (72.7%), haemorrhage 92 (20.8%) and 17 (3%) cases of pregnancy related infection. These three important causes of admission (particularly hypertension) featured prominently in the population of the index study (Table 3). Eighteen women (2.7%) died after admission in the Brazilian study giving a SAMM mortality ratio of 37:1. These deaths were classified as follows:

- Nine direct obstetric deaths (haemorrhage [3], pregnancy related infection [3], pre-eclampsia [1], peri-partum cardiomyopathy [1], acute fatty liver of pregnancy [1]).
- Nine non-obstetric deaths (cardiac [2], neoplasm [2], pneumonia [1], pyelonephritis [1], Gastro-intestinal disorder [1], AIDS [1], other infection [1].

In the index study eight of 302 patients died (2.6%) (Table 24), but it is difficult to compare the causes of death due to the low numbers involved. The results of the index study were achieved against the background of an HIV/AIDS pandemic.

In the Brazilian study the SOFA scores were reported. As expected the total maximum SOFA score was higher in women who died compared to the survivors. The equivalent finding was made in the index study. The mean SOFA score in the Brazilian mortality group was 13.4 (±4.8) while the mean SOFA score in the index study was 12.3 (±2.7) reflecting similar severities of critical illness. The mean SOFA score for the remaining 655 critically ill patients of the Brazilian study was 3.8 ± 3.3, whereas the mean SOFA score for these patients in the index study was 3.3 (3.7). This further supports similarities in the severity of illness. However in the index study four mortalities were related to AIDS and sepsis with an HIV incidence of 21% in the OCCU group (Table 1), whereas there was only one HIV/AIDS case in the Brazilian study. The level 2 and level 3 monitoring and management were similar and will be discussed later. The positive outcome of lower than projected mortality, despite the OCCU being staffed by obstetricians and midwives and not being a general ICU, demonstrates that it is possible to train appropriate staff to provide critical care.

In the Southern Thames region of England, 14 ICU's provided the highest level of care for the referral area. During 2001 obstetric patients with indications for level 2 or level 3 critical care were admitted to the respective general ICU's. The region reported a case-series combining data from all 14 units over a two year period (Hazelgrove et al., 2001). During the study period there were 122 850 deliveries in the region. The main causes for the 210 obstetric admissions were related to pre-eclampsia and haemorrhage, again reflecting some similarity to the index study (Table 3). However in the index study there was the additional burdens of HIV and non-pregnancy related sepsis. Patients received standard level 3 (64%) and or level 2 (36%) critical care management with a reported median APACHE II score on admission of nine (range not reported). Seven women died due to the following causes: pregnancy hypertensive disorders (2), antepartum haemorrhage (1), sepsis (1), pulmonary embolism (1), cardiomyopathy (1), unknown (1). The median APACHE II score of the case mortalities was 20 which is similar to that of the index study (27, see Table 23). The maternal mortality incidence was reported as 3.3% with an obstetric case fatality ratio of 30:1. It should be noted that the 14 ICU's in the abovementioned study, managed 210 admissions over 24 months while 302 admissions were managed in a single unit over a 15-month period in the index study. Despite the challenging caseload and burden of disease, the single obstetric critical care unit in the index study achieved a mortality rate comparable to that of first world institutions.

5.6.3 Severe acute maternal mortality:mortality ratio of Obstetric Critical Care Unit admissions

The importance of identifying and auditing SAMM or maternal near miss has been described earlier. The main advantage of SAMM identification is that it provides a standardised tool for quality assurance in an institution, region or country (Say et al., 2009). In the index study the Mantel et al., SAMM criteria as well as the WHO SAMM criteria were reported (1998; 2009). SAMM was present in all the emergency cases and in 80% (WHO classification) or 65% (Mantel classification) of the total group when step down care and elective admissions were included (Tables 8 & 10). The main causes of SAMM were pre-eclampsia, haemorrhage and sepsis (Table 9). All maternal mortalities had SAMM criteria on admission. The SAMM:mortality ratio in South Africa has been reported from the Pretoria Academic Complex region. In the first audit the ration was reported as 5:1 (Mantel et al., 1998), while after a second audit it had increased to 3.3:1 (Vandecruys & Pattinson, 2002). The pre-eclampsia SAMM:mortality ratio at the Pretoria Academic Complex after the implementation of a strict management protocol was reported as 7:1 during 2005 (Lombaard et al., 2005). The incidence and outcomes of SAMM have not been described elsewhere in South Africa. In the index study the SAMM:mortality ratio was lower than the abovementioned figure being 25:1 (according to the Mantel criteria) and 30:1 (according to the WHO criteria) (Table 10). Netherlands was the first country to report a national SAMM:mortality ratio for obstetric admissions for critical care (29:1; Zwart et al., 2010). This figure is strikingly similar to that of the index study.

The early OCCU studies described earlier in this chapter did not report on SAMM outcomes, although these units often provided level 3 care which is a criterion for SAMM. From the data provided by two studies, one in the USA and one in South Africa (Mabie & Sibai, 1990; Johanson et al., 1995) the SAMM:mortaility rate could be calculated to approximately 30:1. This implies that good quality critical care provided in an obstetric level 3 unit has the ability to prevent or decrease mortality in admissions complicated by SAMM (Mabie & Sibai, 1990; Johanson et al., 1995). The level 2 OCCU studies did not specifically report on SAMM and can therefore not be compared. In the abovementioned Brazilian study reported by Oliveira Neto et al., the SAMM:mortality ratio was 37:1 (2009).

The question could be asked: What is the situation in other African countries? Nigeria is the most populous country in Africa. Osinaike, a consultant anaethetist reported a case series describing 70 obstetric admissions to a general ICU with SAMM in an academic hospital in Ibidan, Nigeria. Respiratory failure and haemodynamic instability were common due to pre-eclampsia (60%), haemorrhage and sepsis. Sadly 36 (52%) of the obstetric admissions died indicating that one in every two patients with SAMM died (2006). The author re-affirmed the importance of early resuscitation and early access to critical care which is often not possible in Nigeria, while lamenting the loss of trained personnel to greener pastures. Ultimately these findings underline the reality of the high incidence of maternal mortality in Africa (Arulkumaran, 2013).

5.6.4 Outcomes of pre-eclampsia severe acute maternal mortality admissions

During the study period the background MMR due to pre-eclampsia in South Africa was estimated to be 23.9/100 000 (Saving Mothers, 2008).

The principles of the abovementioned Mantel criteria were applied to admissions to OCCU for severe pre-eclampsia/eclampsia (index study) in order to generate a SAMM:mortality ratio. This ratio was 118:1 which is much lower than the best reported ratio (7:1) from the Pretoria Academic Complex (Lombaard et al., 2005) and similar to a recalculated ratio from the Brazilian study by Oliveira Neto et al (2009).

The other complications and comorbidities of pre-eclampsia such as major haemorrhage and renal failure, listed in Table 5, further demonstrate the severity of disease in these patients.

While 35 women were admitted with acute renal failure complicating the pre-eclampsia only four required dialysis during OCCU admission or thereafter. None of these women died or developed established renal failure as defined by Bellomo (2005). These good outcomes were facilitated by the critical care support and will be further discussed later.

5.6.5 Outcomes of haemorrhage severe acute maternal mortality admissions

Obstetric haemorrhage is a common primary cause for SAMM and maternal mortality and there are often preventable factors in both developed and developing countries (Sultan, 2013). During the study period obstetric haemorrhage was one of the common causes of obstetric deaths in South Africa. Amongst several avoidable factors were issues of substandard management, inadequate resuscitation, delay in accessing blood products and lack of critical care services (Saving Mothers, 2008). Response time is critical because with haemorrhagic shock and the decrease in oxygen delivery, anaerobic metabolism followed by irreversible shock occurs in time dependant manner. (Marino, 2007).

The OCCU SAMM:haemorrhage mortality ratio was low and comparable to earlier OCCU studies as well as those from Brazil, Netherlands and England (Southern Thames study) (Johanson et al., 1995; Mabie & Sibai, 1990). Before the establishment of the Tygerberg OCCU 3 deaths occurred due to haemorrhage during the three month audit period. In this 15 month period under discussion, no deaths from haemorrhage occurred in patients that were admitted to the OCCU. OCCU patients were managed using early goal-directed resuscitation which included appropriate fluid resuscitation and later blood product administration, ongoing vital observations, invasive monitoring (will follow in discussion) and transfer to theatre when indicated (Marino, 2007; Langenegger & Rout, 2010). The OCCU provided quality emergency and supportive care for patients with haemorrhage who developed SAMM, thereby facilitating a good outcome.

5.6.6 HIV related severe acute maternal mortality

When compared to other studies evaluating OCCU's and obstetric admissions to general ICU's, the most striking and indeed challenging difference was the high incidence of patients admitted with HIV/AIDS (Table 1) with obstetric and non-obstetric complications. During 1990 the Groote Schuur OCCU study reported no HIV+ patients, the incidence of HIV being only 0.8% of the general population in South Africa at that time. This had deteriorated to 12.3% by 2005. The National Department of Health only introduced a new anti-retroviral therapy (ART) programme in 2005. This was later expanded and by mid 2013, 2.3 of the 6.4 million South Africans living with HIV were receiving ART (Simelela & Venter 2014). During 2005-2007 non pregnancy related infections (NPRI) were responsible for 43.7% of the maternal deaths (1729 deaths of which 1347 were proven HIV+). Within the NPRI mortality category 23% of the deaths were ascribed to AIDS (WHO stage IV). In South Africa the HIV+ cases were estimated to have a 10-fold increased risk of mortality compared to non-HIV infected obstetric patients (Moodley & Moran, 2012). In the index study four (62 [6.4%] known HIV+ cases admitted to the OCCU) of the eight OCCU mortalities were associated with HIV/AIDS. Within the context of the South African HIV pandemic many more HIV-associated maternal deaths were anticipated and these certainly occurred at a national level. Due to the extremely limited number of intensive care beds stringent criteria were applied to potential admissions. The practical implication during the study period was that many critically ill, pregnant, HIV+ women could not be transferred to a general intensive care bed. However, under these circumstances critical care support was still offered in the OCCU. This policy allowed cases with potentially reversible pathology, such as bacterial pneumonia or pregnancy-related sepsis (in HIV+ cases), a chance to survive. In South Africa, Ngene et al. reported higher mortality rates for HIV+ obstetric patients admitted to a general ICU than similar HIV- cases (2013). These findings were reinforced in the index study (6.4% for HIV+ patients and 1.7% for HIV- patients). It should be noted that 24 cases admitted to the OCCU had WHO stage IV HIV/AIDS, however only three of these cases demised. In order to achieve these encouraging results, the principles of the surviving sepsis campaign protocol were followed (Dellinger, 2004). Prevention and treatment of HIV must remain a healthcare and post-MDG priority.

5.6.7 Explaining the lower than expected mortality and morbidity

The following section highlights the critical care management provided in terms of special monitoring and advanced organ support.

5.6.7.1 Monitoring of haemodynamic and respiratory parameters in the Obstetric Critical Care Unit

Haemodynamic and respiratory monitoring is the most important facet in critical care management (Marino, 2007). Thorough and continuous clinical assessment is required for the correct diagnosis and management of a patient. The acurate measurement of pathophysiological changes is central to this process.

It is well documented that reliable and accurate invasive blood pressure monitoring is essential for safe and effective control of severe hypertension and is necessary for the administration of continuous, intravenous infusion of vasoactive agents. In fact, this is the only reliable measure to prevent unwanted cerebral, renal and placental perfusion pressure changes (Arulkumaran, 2013; Gogarten, 2009).

Frequent manual and even automated blood pressure (BP) monitoring do not provide true continuous measurements. Proper management of severe hyper- or hypotension in pregnant and non-pregnant patients, requires continuous, reliable and accurate blood pressure monitoring (Marino, 2013). Invasive arterial BP monitoring measures direct pressure and calculates the area under the curve to give a precise mean arterial pressure which is a true indicator of the driving force of blood flow (Marino; 2007). These principles were followed in this study. In the Tygerberg OCCU most arterial lines were inserted by non-specialist personnel such as registrars (residents) and medical officers. Nursing staff received appropriate training in the utilisation of these lines. Only two complications, namely site infections, occurred after line insertion and both responded to antibiotics. There were no vascular injuries (Table 12).

Appropriate intra-arterial monitoring is further supported by a study performed in the Tygerberg OCCU during 2010 which specifically compared the accuracy of non-invasive (automated and manual) and invasive blood pressure monitoring during episodes of acute severe hypertension in cases with pre-eclampsia. In this partially blinded, prospective study, this practice was evaluated. When the gold standard of invasive blood pressure monitoring was compared to the other two non-invasive methods, poor correlation and significant differences in mean systolic blood pressure readings were demonstrated. The authors' findings supported intra-arterial blood pressure monitoring in cases of persistent acute severe hypertension (Langenegger et al., 2012a).

In the clinical setting the arterial blood pressure wave varies or swings between inspiration and expiration, because of dynamic heart-lung interactions. If the patient is fluid depleted, this effect is marked. Modern monitoring systems can calculate the pulse pressure variation. Pulse contour analysis, also included in later monitoring systems, can be used to calculate cardiac output. Therefore, an arterial line provides an additional useful function, namely to guide the assessment of fluid balance.

Another advantage of the intra-arterial line is for convenient, frequent blood sampling eg measurement of respiratory, renal and acid-base parameters. Intra-arterial monitoring was also frequently used in other reported OCCU studies. Only vascular complications were regarded as significant in these studies and insertion site infection was not reported (See Section 5.1). Neither the index study nor the studies referred to in Section 5.1 experienced vascular complications such as arterial aneurysm, embolism or distal ischaemia.

Alongside blood pressure control, fluid management is mandatory in the management of complicated pre-eclampsia. Apart from clinical evaluation, the only continuously available guides to assist in fluid management in the unit were the arterial line (wave form) and the central venous pressure (response to fluid bolus). Pulmonary artery catheters were only available when an experienced operator was on duty. An additional challenge was that most patients in need of fluid resuscitation had ≥1 SAMM such as pre-eclampsia, renal failure and/or major placental abruption (Tables 8-10).

It is well known that measurement of CVP is not without controversy and may be particularly inaccurate in conditions such as pre-eclampsia. The wedge pressure measured with the pulmonary artery catheter is also not predictive of left ventricular pre-load (Kumar et al., 2004). However, in cases when blood pressure was being controlled, and when there was no response to two conservative fluid boluses, a CVP line was sited by the registrar (resident)/medical officer or specialist (Hall, 2004).

A safe technique using the internal jugular site was taught to unit staff. This insertion technique resulted in a low complication rate of only one pneumothorax in 199 placements (Table 12). In other reported studies central venous lines were also frequently placed in level 3 OCCU's, as well as in the Brazilian and Southern Thames ICU's. All units reported low complication rates (See Section 5.1). The CVP measurement is known to be affected by the position of the transducer, ventilatory support, abdominal pressure and individual variation. The correct method is to measure this pressure at the end of expiration, which is indicated by the pressure wave form on the monitor. Unless the CVP was high (> 6-12mmHg), a 200ml crystalloid fluid bolus was administered after determination of this pressure without changing the position of the patient. After 30 minutes this measurement was repeated to determine the trend of the volume pressure curve. In cases without a clinical response, signs of pulmonary oedema and no rise in CVP, further boluses were administered carefully in the same manner until the CVP value increased and/or a clinical response was noted. If this pragmatic method failed the doctor contacted the duty consultant to discuss the availability of PAC monitoring using haemodynamic studies. In most cases, including patients with pre-eclampsia and oliguria this CVP-directed approach was successful in preventing renal failure. Patients with acute renal failure were managed in the same fashion in cooperation with renal subspecialists. Amongst 46 patients with acute renal failure, only two patients developed iatrogenic fluid overload resulting in pulmonary oedema, which was quickly identified and managed (Table 12). The use of PAC's will be described shortly. The use of central venous lines was also in accordance with the recommendations of the "Surviving Sepsis Campaign" which directs fluid administration during oliguria, prescribes the route of adrenaline infusions and the measurement of central venous oxygen saturation (Dellinger 2008). In addition central lines are regarded as standard practice to guide fluid administration and oxygen delivery during resuscitation, eg severe haemorrhage.

Not only is the use of central venous pressure contestable (as mentioned above) but in similar fashion the use of wedge pressure measured using pulmonary artery catheters has also been questioned in predicting fluid responsiveness (Kumar et al., 2004).

A CVP measurement as well as a wedge pressure measurement (using PAC balloon occlusion) determines pressure while the clinician actually needs to assess the end-diastolic volumes of the left and right ventricles. The goal of the clinician is to increase stroke volume.

The largest randomised trial, now more than 10 years old, has questioned whether PACs as monitors of fluid responsiveness and cardiac output, really improve patient outcomes (Yu et al., 2003). It must be pointed out that unless PAC methods and readings are not meticulously performed they are of little value.

Apart from demonstrating the response to fluid therapy, PACs have the advantage of providing information on several other parameters such as oxygen delivery and uptake, as well as cardiac output. These parameters are certainly useful in the management of specific pathology (Vincent, 2014). However, what non-randomised studies often fail to point out is that the PACs were used in the sickest patients with the poorest prognoses. In this regard, Marino emphasizes that PAC catheters are not in themselves a form of therapy (2007).

The Tygerberg OCCU had the equipment and consumables available to insert PACs but these were only utilised during the daytime due to the lack of experienced staff. This fact could explain the lower rate of PAC insertion compared to two other OCCU level 3 units (Mabie & Sibai, 1990; Johanson et al., 1995). Similarly reported use of PACs in level 2 OCCU's was also low (Zeeman et al., 2003). PACs still have a place in the management of selected cases such as severe mitral stenosis with pulmonary hypertension or patients with pre-eclampsia and acute renal failure. However, they are now used infrequently due to the large number of skilled personnel (technicians and trained doctors and nurses) necessary to meticulously manage this monitoring modality. This situation has led to the investigation of alternative methods of assessing fluid responsiveness. Pulse pressure waveform variation analysis is one option but is considered inaccurate unless the patient is receiving positive pressure ventilation and preferably paralysed (Vincent & Gerlach, 2004; 2013). This method was not available to the OCCU during the study period.

In a recent review Arulkumaran pointed out the limitations of CVP, PAC and arterial wave analysis in estimating and directing fluid status and volume response in pregnancy (Arulkamaran, 2013).

Echocardiography has been presented as the most reliable monitoring tool for fluid assessment in these circumstances (Belfort et al., 1997). Once again this is another method that requires specialised equipment, training and expertise in order to be a practical option.

Echocardiography is only an option for selected and not routine critical care cases. This technique is not able to monitor biochemical changes such as acid base balance, lactate and venous oxygen saturation. Currently echocardiographic assessment of ventricular function, aortic cardiac output, stroke volume and left atrial pressure is the ideal and safest method to guide therapy in critical care where it is available.

In conclusion, the index study has shown that the pragmatic combination of clinical assessment and a CVP-directed approach to fluid management can be used in the safe management of complicated cases to achieve adequate oxygen delivery.

5.6.7.2 Respiratory support in an Obstetric Critical Care Unit

Intubation and mechanical ventilation is often an indicated, life-saving intervention. It does not however, treat the disease. On the contrary it is associated with lung injury due to baro-trauma, volume-trauma and bio-trauma. Ventilator associated pneumonia is another complication. For this reason invasive mechanical ventilation is associated with increased risk of morbidity or mortality (Slutsky, 2005; Hess, 2011). When respiratory support is necessary, it is then sensible to consider alternative non-invasive methods that decrease the risk of complications.

The policy of the Tygerberg ICU for patients admitted with respiratory distress was to provide safe CPAP and/or BiPAP. This level 2 intervention was more familiar to the staff.

The most common causes of respiratory failure in conscious patients were pulmonary oedema secondary to pre-eclampsia or cardiac pathology, and pneumonia (Table 16). In fourty seven cases of pre-eclampsia-related pulmonary oedema leading to respiratory failure did not respond to initial management with furosemide, blood pressure control, morphine and face mask oxygen. The next step-up in support was to provide non-invasive positive pressure ventilatory support such as CPAP and/or BiPAP. This positive pressure support immediately decreases the work of breathing as the pressure assists the patient during the energy consuming process of generating negative intra-thoracic pressure in order to inhale. Exhalation is a passive process. A valve system allows for easier inspiration as well as expiration. CPAP also prevents alveolar collapse and the increased alveolar pressure increases the gradient of fluid flow from the alveolus to the lymph drainage of the lung (Marino, 2007).

Ninety-five percent of this group of patients were comfortable on CPAP. Their pulmonary oedema resolved and they were soon stable enough to require only face mask oxygen. Only two patients on CPAP only became unco-operative and removed the masks which resulted in rapid hypoxia requiring intubation and ventilation. (Table 16).

Respiratory failure and arrest is one of the common final causes of maternal mortality in South Africa (Saving Mothers, 2012). CPAP is a simple life-saving respiratory support modality that is easy to implement in the OCCU and requires minimal skills training. Despite this fact, it is surprising that it has not been recommended in the regular Saving Mothers reports. Neither was CPAP reported in any other OCCU study (See Section 5.1). The earlier CPAP studies demonstrated it to be effective in patients with exacerbation of COPD and patients with sleep apnoea (Brochardt et al, 2002).

CPAP was initially used in patients with chronic obstructive pulmonary disease (Brochardt et al, 2002). It was next utilised in general ICU's as step-down support after successful invasive ventilation. It remains under-utilised as a primary form of ventilatory support.

In the index study CPAP and Bi-PAP provided adequate respiratory support for pulmonary oedema and community acquired pneumonias. As respiratory support methods CPAP and Bi-PAP fall within the same category although CPAP is always performed first. What is of importance is to avoid invasive ventilation that by implication requires intubation. By performing CPAP and Bi-PAP in appropriate cases invasive ventilation and intubation was avoided in 76% of cases. This practice can certainly be replicated in other tertiary and regional hospitals in South Africa. However, although these techniques seem especially suitable to decrease maternal morbidity and mortality in low and middle income countries, there is no reason why this approach cannot be successfully adopted in high income countries where it is speculated that indications for level 2 support and SAMM is still under-diagnosed (Scrutton & Gardner, 2012).

Unfortunately intubation and invasive ventilation cannot be entirely avoided. The most common cause for intubation either in the OCCU, theatre or referring hospitals was severe systemic sepsis. Other causes included complicated pre-eclampsia requiring an operative theatre procedure eg caesarean section or complex cardiac disorders. Because intubation is still regularly required, personnel working in labour wards and OCCU's must receive the necessary training. Ultimately all community and Level 1 hospital healthcare staff must be trained to recognise respiratory dysfunction, and administer oxygen early. This must be followed by expeditious referral. More advanced skills must be taught at level 2 hospitals and CPAP should be available there. OCCU's should be available at tertiary care centres. Naidoo is of the opinion that even if all public and private general critical care resources in South Africa are combined in the proposed National Health Insurance system, a shortage will still remain (2012).

5.6.7.3 Administration of infusions of vaso-active drugs

The ability to safely administer vaso-active drugs under appropriate monitoring, especially intra-arterial blood pressure monitoring is a key function of the OCCU. The previously described Level 2 OCCU's referred patients to general ICUs for administration of inotropes and nitrates. The Tygerberg OCCU was able to safely administer inotropes in 34 patients with pathology ranging from septic shock to acute heart failure syndromes (Table 17).

The advantage of an obstetric critical care unit is that it recognises the particular importance of accurately monitoring blood pressure in patients with pre-eclampsia. This allows the safe administration of intravenous drugs such as labetalol and dihydralizine for effective control. It is even possible to set lower and upper limits for mean arterial pressure (MAP) in cases with pre-eclampsia and eg brain oedema. Cerebral pathology has been shown to be a major cause of morbidity and mortality in pre-eclampsia (Moodley, 2008; Gogarten, 2009).

5.6.7.4 Dialysis in the Obstetric Critical Care Unit

Four patients admitted to the Tygerberg OCCU met the local criteria for dialysis. These patients had severe pre-eclampsia in the labour ward that was then complicated by another insult, such as high spinal anaesthetic, major haemorrhage and/or septic shock. The dialysis of these four patients was performed in and therefore with the support of the OCCU. The Tygerberg Renal Unit provided a mobile dialysis machine operated by their technician to the OCCU. Patients with this degree of illness would not be candidates for dialysis in the Tygerberg Renal Unit itself due to lower levels of available support.

5.6.7.5 Transfer to a general Intensive Care Unit

Due to the limited availability of all ICU resources for the large local population, the Tygerberg OCCU was obliged to create capacity to care for patients with valid admission criteria to a general ICU. In this sense, the number of general ICU transfers from the OCCU did not reflect the true need for level 3 care. Many of the patients admitted to the OCCU developed or had existing indications for level 3 care (on admission) but could not be transferred due to lack of general ICU capacity. It should be noted that nearly a third of the OCCU admissions required level 3 care for different durations of time (12-48 hours). Thirty eight patients received all of their level 3 care in the OCCU.

In contrast to this pragmatic approach, studies from developed countries such as the USA, have a two-tiered system where patients are either directly transferred to a general ICU or admitted to an OCCU. Should the patient's condition deteriorate, on-site assistance is provided and the patient is then transferred to a general ICU (Zeeman et al., 2003). Even if OCCU's were available in all academic centres in South Africa (which is not the case), such ideal functioning would hardly be possible. The index study demonstrated that the Tygerberg Obstetric Critical Care Unit provided two specific benefits. Firstly it created specific critical care capacity and secondly when transfer to a general ICU was necessary and possible, patients were transferred in a more stabilised condition.

5.6.8 New morbidity that developed after the Obstetric Critical Care Unit admission

Clinical risk management in an OCCU is essential to ensure an appropriate standard of care. In Table 19 "critical incidents" are listed which are designed to trigger a response for review and are also used to determine outcomes of management. Other published OCCU studies lack detail in this regard, limiting their findings mainly to the complications of invasive lines. A strength of the index study is that reported complications are clearly defined and were accurately documented, although it was sometimes difficult to differentiate the natural cause of disease from complications of management. Examples of the latter include the interventions of intubation, dialysis and cardiac arrest. It is well understood that all interventions entertain the risk of complication. Respiratory support was complicated by two cases of aspiration during intubation. Both cases recovered fully. The two pneumothoraces following one PAC and one central venous catheter insertion are a warning that all patients must have a chest X-ray after central line placement. The two cases of pulmonary oedema may have followed iatrogenic fluid overload as this developed after recurrent fluid boluses, but this was actively sought, detected early and quickly resolved by furosemide and mask oxygen. Although nosocomial pneumonia remains a potential risk especially after ventilation, only six cases in the index study developed this condition. Another five developed a superficial infection at a cutaneous insertion site which was easily treated with antibiotics. The low rate of iatrogenic infection reflected the strict level of infection control. One of the advantages of an obstetrical critical care unit, is that the population and conditions managed there are sufficiently different from those of general ICU's to anticipate shorter durations of admission. These differences also correspond to a differential risk of infectious conditions. In the index study, the local infection control committee deemed it safe to allow babies to be "roomed in" with their mothers when both were stable enough. During the study period there were no outbreaks of multi-drug resistant staphylococcus aureus, and resistant acinitobacter which were occasionally present in the general ICU's. Patients with a drug resistant organism were not allowed to be stepped down from the general to the obstetric ICU. Ultimately the low rate of critical incidence was facilitated by appropriate orientation, strict protocols and in-service skills training programs.

5.6.9 Length of stay

In the index study the median length of OCCU stay was comparable to that of the level 2/3 OCCU's described by Mabie & Sibai and Johanson et al. (1990, 1995). When an obstetric patient with organ dysfunction is managed appropriately in a dedicated critical care unit, the underlying pathology can usually be quickly reversed, allowing safe transfer to a lower level ward. This has the effect of creating further capacity within the critical care unit. Long term ventilation should preferably be avoided as this has the opposite effect.

5.6.10 Maternal deaths outside of any Obstetric Critical Care Unit care during the study period

During the study period, all maternal deaths at Tygerberg Academic Hospital were traced and reviewed. Those that received any form or duration of OCCU care (n=8) have already been discussed). Those that did not receive such care, are discussed here (n also = 8).

Four pregnant patients died soon after arrival in the medical emergency admissions division. Two had respiratory failure and HIV stage IV, one died due to cerebral infarction of unknown cause while the other had an acute collapse 3 weeks after delivery without ascertainment of a definite cause. Two patients with major haemorrhage were transferred directly to the emergency theatre due to the advanced stage of their haemorrhagic shock. They both underwent emergency hysterectomy but died shortly thereafter, one with cardiac arrest in the recovery room and the other with multi-organ failure in the Surgical ICU. Another patient who had an uncomplicated caesarean section developed cardio-respiratory arrest after complaining of chest pain in the recovery room. The cause of death in this case was confirmed pulmonary embolism. The final patient succumbed to extensive burns in the Burns Unit.

5.6.11 Neonatal outcome

An important difference in this study compared to other published OCCU levels 2 and 3 studies was the high (45%) proportion of antenatal admissions. This figure ranges from 11-20% in other reported studies. The high proportion of undelivered admissions was probably due to good communication and clear referral guidelines for the OCCU. In reality the OCCU was only able to impact upon viable, undelivered pregnancies. There were 110 such patients meeting the Tygerberg criteria.

The supportive care provided by the OCCU increased cardiac output and thereby uterine perfusion. The goal was to maintain a safe environment for the unborn baby. For example, the target pH was ≥7.3 (normal pregnancy value ±7.4) with an oxygen saturation of ≥94% as described by Foley, 2004. The goal of these specific targets is to optimise the fetal haemoglobin oxygen dissociation curve and prevent the fetus from becoming a bicarbonate donor to an acidotic mother. It is important to note that fetal acidosis predisposes to cerebral damage.

In the OCCU continuous fetal heart rate pattern was available and betamethasone (which enhances fetal pulmonary maturity, decreases necrotising enterocolitis and decreases intracerebral haemorrhage significantly in preterm babies) was administered even when there was a risk for maternal pulmonary oedema. The careful support and monitoring also provided the opportunity to consider induction of labour where appropriate. Together these measures resulted in a neonatal mortality rate (all viable births up to 28 days) of only 7%. This impressive figure could not be compared to other OCCU studies as their rates were not reported, possibly due to low numbers of undelivered admissions.

The index study demonstrated that antenatal care needs to be continued even within a critical care environment that is primarily focused on reducing maternal morbidity and mortality. The encouraging neonatal results demonstrate that this is certainly achievable.

5.7 Conclusion

This leg of the study demonstrated that the encouraging results obtained in Chapter 4 (before and after studies) were maintained and expanded during the first 15 months of the newly established unit. A low maternal mortality rate of only 2.6% and an encouraging SAMM:mortality ratio of 30:1 were achieved through the provision of levels 2 and 3 emergency care. These figures compare very favorably with those of high income countries.

Respiratory distress and resistant acute severe hypertension were two specific common organ system failures requiring urgent attention. The described relatively simple and reproducible forms of respiratory support were very effective, while invasive intra-arterial monitoring and safe continuous intra-venous administration of anti-hypertensive drugs and nitrates addressed the latter challenge. Ultimately the Tygerberg OCCU provided three benefits. Firstly it created specific critical care capacity, thereby reducing maternal mortality and morbidity. Secondly when transfer to a general ICU was necessary and possible, patients were transferred in a more stabilised condition. When transfer was not possible, level 3 support was continued in the OCCU to achieve the same goal. Finally uniquely favorable neonatal outcomes were demonstrated.

5.8 References

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Photo: Combined academic ward round in the Obstetric Critical Care Unit

From left to right: Sr Michaels, Alrisah Le Roux, Prof David Hall, Jonathan Bourke, Eduard Langenegger, stable patient, Samier Jacobs, Judy Kluge, Elbie Viljoen
**With patient persmission*

CHAPTER 6: ESTABLISHING AN OBSTETRIC CRITICAL CARE UNIT IN A SOUTH AFRICAN TERTIARY HOSPITAL

6.1 Reflection on the thesis

The MDG number five (to decrease maternal mortality by three quarters by 2015) was not achieved in South Africa. In fact it remained amongst the highest in the world, and has not decreased since 1990. The obstetric community and National Government have remained committed to decrease mortality. The recommendations of the triennial Saving Mothers reports as well as the WHO have been implemented with varying success.

The direct and indirect causes, as well as the final causes of maternal deaths are well documented. The factors leading to probable preventable maternal deaths are also known and remain persistently high, even in tertiary hospitals.

When a patient suffers acute severe maternal morbidity and or organ dysfunction/ failure the risk of mortality in South Africa is much higher compared to higher income countries. The provision of more advanced emergency services and obstetric critical care will decrease morbidity and mortality. The common factors leading to potential preventable mortalities are the following: lack of sufficient critical care resources, substandard monitoring and response, substandard management of morbidity and sub-standard resuscitation.

There exists a current need to evaluate the provision of obstetric critical care services in South Africa. Evidence is needed to predict the potential impact of such a service. There are no recent tested detailed models for such a service, nor criteria to identify which patients will benefit from obstetric critical care intervention, expected main causes of critical illness and no evidence-based interventions or outcomes. Due to these uncertainties as well as limited resources, the establishment of OCCU's are not one of the current recommendations to target preventable mortality.

Prior to the index study the institutional incidence of maternal mortality was high and a large proportion of these were possibly preventable. The question was: "Would the establishment and efficient use of an OCCU in the labour ward decrease maternal mortality and morbidity in critically ill obstetric patients at the institution".

The aim of this thesis was to establish and then study the impact of the OCCU in a tertiary labour ward in South Africa. A unique detailed OCCU blueprint was developed. After implementation the planned unit was able to provide an effective critical care service. This tested blueprint now provides incorporates evidence-based guidance on design, engineering and clinical standards for an OCCU in a South African (or equivalent) tertiary obstetric service. This proves that the establishment of an obstetric critical care unit in a resource-limited environment is now an achievable challenge.

The before and after comparison leg of the study demonstrated a statistically significant decrease in maternal mortality when comparing critically ill obstetric patients managed in the tertiary labour ward before and after the establishment of the OCCU. This unique comparative study provided reliable evidence (level 2a) in support of the establishment of a dedicated OCCU within a South African metropolitan tertiary labour ward. The positive results in the "before and after study" were confirmed in the large cohort of obstetric critical care patients managed in the newly established OCCU. It demonstrated a low maternal mortality rate as well as a very low SAMM:mortality ratio, that is even comparable with higher income countries. This large prospective study also provided valuable epidemiological information in terms of the need and requirements for an obstetric critical care service in a metropolitan low socioeconomic population.

The principal reason for the improved outcomes was the quality obstetric critical care management received. The OCCU provided the platform for effective basic and then advanced resuscitation, appropriate monitoring of physiological variables, haemodynamic assessment and support, and non-invasive as well as invasive respiratory support. The unit also provided the opportunity to support and monitor the fetus.

The provision of obstetric critical care for patients with SAMM in labour wards will decrease maternal mortality and long term morbidity. The efficient use of the OCCU addressed preventable maternal death factors such as: substandard monitoring and response, substandard emergency care and resuscitation and ultimately the remaining lack of critical care resources. In summary, the unit provided the platform for obstetricians and midwives to provide quality obstetric and critical care management.

This thesis now provides the much needed information and supportive evidence to expand much needed obstetric critical care in South Africa. However, severe maternal morbidity and preventable mortality is not unique to South Africa. Other neighbouring African countries with similar challenges and resources will also benefit from establishing obstetric critical care units within their obstetric services.

SAMM audits conducted in higher income countries demonstrated that morbidity was often underestimated. Even though the maternal mortality rate was lower, a large proportion of maternal deaths were classified as potentially avoidable. They also reported that some of the potentially preventable mortalities occurred outside intensive care units.

The increased risk of long term morbidity and mortality in patients with SAMM is not disputed and they will benefit from appropriate critical care management. However it was predicted that if all patients with SAMM in the United Kingdom were admitted to existing general critical care units, there would probably be insufficient critical care capacity. This model can therefore also be used in high income countries in order to provide necessary care.

6.2 Recommendations

The authors recommend that obstetric critical care services in the form of OCCU's are paramount at similar institutions to provide support for obstetric patients with organ dysfunction and or failure.

The key interventions for the effective management of patients with severe morbidity in the OCCU were the following:

- Basic critical care training.
- Intra-arterial blood pressure monitoring and control must be used in the following cases:
  - Pre-eclampsia with resistant severe hypertension to assist strict control

- Pre-eclampsia with organ dysfunction (pulmonary oedema, cerebral oedema) to calculate and monitor perfusion pressures.
- Severe sepsis, severe haemorrhage in order to accurately measure blood pressure and maintain mean arterial pressures above 65-70 to ensure organ perfusion
- Monitoring to facilitate safe vasoactive drug infusions
- Cardiac disorders
- Indications for frequent arterial blood gas sampling.

- Central venous line placement to assess and monitor fluid status when indicated. Patients with severe sepsis, haemorrhage, pre-eclampsia and resistant oliguria need assessment and management of volume status.
  - Measure the change in central venous pressure after a fluid bolus (Calculated at end-expiration on the central venous monitor pressure curve).
  - Interpret stroke volume variation using the arterial wave pressure curve.
- Implementation of non-invasive respiratory support methods CPAP and Bi-PAP for respiratory failure, especially for pulmonary edema and pneumonia.
- Create emergency capacity to temporarily intubate and ventilate when no ICU beds available or as part of advanced life support during resuscitation.

Dr Carter, the newly appointed Deputy Director General of National Health, in his talk on his experience and view of the impact of OCCU during the study period commented: *"I saw miracles happen, within one year we could demonstrate a reduction in avoidable maternal deaths".* The authors want to encourage the replication of this model throughout South Africa and similar countries in order to allow *"miracles to happen".*

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