Medication storage in Emergency Medical Services: Temperature ranges from a South African sample

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ABSTRACT

Background: Pre-hospital emergency care providers working in emergency medical services (EMS) are licenced to administer medication to the acutely ill and injured. In South Africa, there are significant seasonal variations in temperature, sometimes far exceeding the recommended medication storage temperature. The aim of this study was to determine the summer temperature ranges inside select emergency vehicles and storage facilities in four provinces in South Africa.

Methods: A prospective, observational study was conducted in four (Cape Town, Western Cape; Johannesburg, Gauteng; Durban, KwaZulu-Natal; Potchefstroom, North West) provinces during the summer (February – March) months of 2019. A continuous temperature monitoring device was placed in the medication storage room, the response vehicle drug bags, and an ambulance at a single private EMS base in each of the provinces. Temperature data were recorded in fifteen-minute intervals. The data were extracted after six weeks and subjected to descriptive analysis. Data were also analysed in six-hourly strata to account for daily temperature variations.

Results: A total of 36 002 temperature readings were recorded during the study period. The mean (range) temperature across the four bases was 25.4°C (13.1–56.8) for ambulances, 25.7°C (13.3–49.1) for primary response vehicles, and 24.4°C (17.3–33.9) for medication storage facilities. The highest mean (range) temperatures, of 33.7°C (20.4–47.9), were recorded in a Johannesburg-based primary response vehicle between 12h00 and 18h00.

Conclusion: Current medication storage and transportation practices in the pre-hospital setting do not maintain temperatures according to the recommended storage conditions. Further investigation should address the implication of temperature fluctuations on medication degradation, and a sustainable, cost-effective solution should be developed to store medication in the pre-hospital setting.

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BACKGROUND

Pre-hospital emergency care providers in emergency medical services (EMS) administer various medications for the acute management of emergency conditions. Good pharmacy practise specifies that medication storage conditions are based on the manufacturer's recommendations, typically below 25°C for ambient storage.[1] For medications requiring cold-chain management, a fridge or cooling box should be used to maintain optimum temperatures, commonly between 2°C and 8°C.[1]

In South Africa, temperatures vary significantly between the summer and winter months, and between provinces within the same season. Temperatures differ from below freezing point during the winter to above 40°C in summer.[2] In the South African EMS setting, before medication is issued to pre-hospital emergency care providers, it is stored in an access-controlled stock room. After the medications are issued, pre-hospital emergency care providers are required to store medications in a grabber bag kept inside the ambulance or primary response vehicle until it is administered to a patient or returned to the stock room, if unused. While it is a requirement that these medications be stored under controlled temperature conditions, it is uncertain whether this is enforced, effective, or feasible in this setting.

Notwithstanding a few small studies from Johannesburg,[3,4] temperature ranges in EMS vehicles and storage facilities have largely been unstudied in South Africa. This study aimed to determine the temperature ranges inside select emergency vehicles and storage facilities in four provinces in South Africa during the summer of 2019. The results of this study may inform temperature control measures and grabber bag insulation and design to protect emergency medications from potential degradation under realistic conditions.

DESIGN AND METHODS

We performed a prospective, observational study to determine the temperature ranges inside emergency vehicles (ambulance and primary response vehicles) and the medication storage facilities of a large national private EMS provider.

The study was conducted over a six-week summer period (February – March 2019). Four EMS bases were selected based on their differing summer climates across the provinces: Johannesburg, Gauteng; Cape Town, Western Cape; Potchefstroom, North West province; and Durban, KwaZulu-Natal. An AD-102 Sensit (0.5°C accuracy) temperature monitoring device (Q&A Instruments, Cape Town) was placed in the medication grabber bags of one rapid response vehicle and one ambulance per province. Medication grabber bags were not intended for cold-chain maintenance, and bags did not contain any ice packs or cooling devices. Additionally, a sensor was placed in the medication storage room of the EMS bases for each of the vehicles. The temperature was not intentionally controlled in these storage facilities.

The temperature sensor recorded and transmitted temperature readings every fifteen minutes and uploaded data to a cloud-based repository. Humidity was also measured but was not the focus of this manuscript. After the six-week period, data were extracted to a Microsoft Excel spreadsheet (Microsoft Corporation, Washington, United States of America) and subjected to descriptive analysis. Data were grouped into six-hour intervals to compare the different times of the day.

Since no human participants were enrolled in this study, no ethical approval was sought. However, study approval was obtained from the research committee at the private EMS companies before data collection commenced.

Table 1: Temperature Ranges in Western Cape Province mean °C (range)

Times	**Ambulance**	**PRV**	**Medication Storage Facility**
All Times	*28.0 (19.1–33.4)	25 (19.0–35.9)	22.7 (17.9–26.4)
00h00–06h00	23.6 (20.4–29.4)	*25.1 (20.0–32.9)	22.9 (18.3–25.5)
06h00–12h00	23.2 (20.4–27.4)	23.5 (19.0–28.5)	22.3 (17.9–25.4)
12h00–18h00	*26.7 (20.5–33.4)	24.8 (19.1–35.9)	22.6 (18.0–26.4)
18h00–00h00	*25.7 (19.1–31.3)	*26.6 (20.3–35.9)	22.9 (18.6–26.3)

PRV = Primary Response Vehicle, *Indicates mean temperatures out of recommended ranges.

RESULTS

A total of 36 002 temperature recordings were extracted and eligible for analysis. The mean (range) temperature across the four bases was 25.4C (13.1–56.8) for ambulances, 25.7C (13.3–49.1) for primary response vehicles, and 24.4C (17.3–33.9) for medication storage facilities. The mean temperatures for each of the locations and temperature fluctuations according to time of day are outlined in Tables 1–4.

Table 2: Temperature Ranges in KwaZulu-Natal Province mean °C (range)

Times	**Ambulance**	**PRV**	**Medication Storage Facility**
All Times	*26.4 (15.9–43.3)	*26.0 (17.8–49.1)	*27.0 (21.3–31.3)
00h00–06h00	24.7 (20.9–30.1)	23.8 (18.1–31.1)	*26.4 (21.3–29.4)
06h00–12h00	*25.4 (15.9–38.9)	23.6 (17.8–35.6)	*26.1 (21.3–29.6)
12h00–18h00	*28.9 (19.8–43.3)	*30.0 (20.9–49.1)	*28.1 (25.1–31.3)
18h00–00h00	*27.1 (19.3–33.0)	*26.6 (21.9–41.3)	*27.6 (24.6–30.5)

PRV = Primary Response Vehicle, *Indicates mean temperatures out of recommended ranges.

Table 3: Temperature Ranges in Gauteng Province mean °C (range)

Times	**Ambulance**	**PRV**	**Medication Storage Facility**
All Times	24.6 (13.1–56.8)	*27.4 (16.4–47.9)	23.4 (17.3–33.9)
00h00–06h00	19.8 (13.6–26.1)	23.3 (16.6–31.4)	21.4 (17.5–25.4)
06h00–12h00	23.6 (13.1–47.3)	22.8 (16.4–40.8)	20.9 (17.3–26.3)
12h00–18h00	*31.9 (18.9–56.8)	*33.7 (20.4–47.9)	*26.3 (18.5–33.9)
18h00–00h00	24.3 (17.9–34.4)	*30.0 (20.0–43.8)	24.9 (18.1–33.6)

PRV = Primary Response Vehicle, *Indicates mean temperatures out of recommended ranges.

Table 4: Temperature Ranges in North West Province mean °C (range)

Times	**Ambulance**	**PRV**	**Medication Storage Facility**
All Times	*25.8 (16.4–45.8)	24.7 (13.3–46.9)	24.1 (18.5–31.6)
00h00–06h00	21.8 (16.9–26.6)	18.8 (13.6–23.9)	23.8 (19.6–26.4)
06h00–12h00	23.2 (16.4–36.8)	21.3 (13.3–34.5)	23.8 (18.5–29.8)
12h00–18h00	*31.4 (19.6–45.8)	*32.8 (19.5–46.9)	25.0 (19.0–31.6)
18h00–00h00	*27.1 (185–40.6)	*25.9 (18.6–38.5)	24.1 (18.5–29.1)

PRV = Primary Response Vehicle, *Indicates mean temperatures out of recommended ranges.

DISCUSSION

This study found that temperatures ranged from 13.1°C to 56.8°C in emergency vehicles and 17.3°C to 33.9°C in medication storage facilities. The highest mean (range) temperatures (33.7°C (20.4–47.9)) were recorded in the Johannesburg-based primary response vehicle between 12h00 and 18h00. All vehicles, both ambulances and response vehicles, exceeded 25°C. Storage facilities in two of the four areas (Potchefstroom, North West and Cape Town, Western Cape) maintained recommended mean temperatures, but still showed maximum temperatures exceeding 25°C.

The maximum temperatures recorded in our study did exceed that of a previous study from Johannesburg.[3] Research from Europe[5] and America[6] have reported similar maximum temperatures. Very little is known about medications' stability profile in the pre-hospital setting, especially when subjected to significant variation and high temperatures. It has been suggested that medication such as morphine will maintain its efficacy outside the recommended 25°C limit. In the case of midazolam, degradation was reported independently of temperature, whereas atropine and naloxone showed significant degradation at high temperatures.[6] While the effect of such degradation on drug efficacy and patient safety is yet to be determined, it is essential that policymakers implement strategies to either procure medications that are more stable (where possible) or develop and enforce policy to allow for stricter temperature control.

It has previously been recommended that medication should be stored in thermo-labile boxes.[7] With space being a commodity in most ambulances and response vehicles, these boxes would need to be tested for appropriateness and durability in the field. Commercially available solutions can cost as much as R13000–R16000 ($899–$1119),[8] making this solution financially unattainable for many resource-constrained systems. There is thus a need to obtain a suitable, cost-effective solution for the storage of medication in ambulances and response vehicles.

Response vehicles and ambulances are constantly

moving and are therefore sensitive to changes in ambient temperature. In the absence of adequate insulation, medication grabber bags would then also be subjected to such temperature changes. This was demonstrated in our study, where large variations were seen in the temperature ranges in emergency vehicles. However, these fluctuations in temperature would not be expected in medication storage facilities, an area that should be access and temperature controlled. Yet, in our study, there was still considerable temperature variation in medication storage facilities. While the reasons for this variation may only become evident after site inspections, it is speculated that this may be due to medication being stored in cabinets in offices or other rooms without adequate climate control. Explanations and possible solutions should be sought in future studies.

An important consideration for temperature extremes in storage facilities is the effect of temperature variation on medication shelf-life. Owing to the degradation of some medications at high temperatures, frequent stock replacement has been recommended.6 However, this might have significant implications for the supply chain, procurement processes, and cost. EMS in low-resource settings with warm climates (such as in sub-Saharan Africa) should take particular note of these results and implement means of controlling the temperatures at which medication stock is stored.

LIMITATIONS

This study did not account for all the provinces in South Africa, and as such, the generalisability of the results to the other provinces in the country is limited. However, we do believe that the concern of temperature exceeding that recommended for storage is universal. Additionally, this study was not conducted across the entire South African summer period, and results may not be generalisable to other summer months. Future research might consider studies that account for all seasons and annual temperature fluctuations. Moreover, this study sought to determine the temperature variation of medications under typical storage conditions, and thus did not explore temperature variation for cold-chain storage facilities – normally stored in fridges and cooler bags with ice packs. Future studies should seek to determine the temperature variation under such storage conditions.

CONCLUSION

Current medication storage and transportation practices in the pre-hospital environment do not maintain temperatures below 25°C. It is unclear what implications these temperature variations will have on medication degradation or patient safety. We recommend that this be approached in the following manner:

1. Best practice should be developed for the storage and transportation of medication in the pre-hospital setting. This should be context-specific, and special attention should be given to the cost-effectiveness, reliability and appropriateness of solutions offered. 2. Medications' stability or degradation at varying temperatures should be taken into consideration when policymakers are deciding on which medications are appropriate for use in the South African EMS setting.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest.

AUTHOR CONTRIBUTIONS

All the authors were involved in the conceptualisation and interpretation of results. NH and CW collected the data. SR analysed the data. CW and WS drafted the manuscript. All the authors approved the final version to be published and agree to be accountable for all the aspects of the work.

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