Thermal fatalities in Pretoria: A 5-year retrospective review

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Highlights

•Fatalities in children between the ages of 0–4 years were disproportionately high.
•A significant proportion of fatalities were as a result of suicide.
•More than two thirds of indoor fatalities occurred in shack fires.
•BAC's were high at 0.09 g/100 ml and were higher in fatalities involving shack fires at 0.14 g/100 ml.
•In a significant number of scene fatalities (92.2%), the decedents were charred beyond recognition.

Abstract

In South Africa, research on burn mortality has emanated primarily from specialised burn centres and has focused on specific age groups and hospital-based fatalities. This study describes the demographic profile and the pathology of trauma related to burn fatalities as seen at the Pretoria Medico-Legal Laboratory (PTA MLL), a large urban medico-legal mortuary over a 5-year period from January 2011 to December 2015. Mortuary admission records and autopsy reports were used to gather information on demographics, circumstances of injury, apparent manner and cause of death, pathology of burns, toxicology and histology reports and identification of the decedents.

Results

Of the 9558 unnatural deaths admitted to the PTA MLL during this time period, 291 (3.0%) of the fatalities met the inclusion criteria. The male:female ratio was 2.9:1. Most fatalities occurred between the ages of 0–4 years. One hundred and forty-two (142) decedents were charred beyond recognition. Identification was confirmed in 134 (94.4%) of the charred remains. In 208 (69.8%) of the cases the manner of death was deemed to be accidental, 23 (7.9%) were homicidal and 11 (3.8%) were suicides. Two hundred and fifty-five (87.4%) of the fatalities were as a result of open flames/fires. Shack fires were responsible for 105 (36%) of all fatalities. In 32 (11.0%) cases of open flame/fire fatalities where death occurred at the scene of injury, more than one fatality was reported per incident. In 122 (79.2%) of scene fatalities, soot deposition was noted in the upper and lower airways. Forty-five (32.8%) of hospital fatalities occurred within 24 h of admission. The most common complications in hospital fatalities were from the respiratory system. The mean blood alcohol concentrations (BAC) was 0.09 g/100 ml. The mean carboxyhaemoglobin concentrations (COHb) was 19.9%. All available cyanide results were negative.

Conclusion

The study is the first of its kind in South Africa to generate bimodal descriptive statistics for burn fatalities. Approximately 3% of unnatural deaths at the PTA-MLL were due to burns, occurring at a rate of ±1 death per week. The data provides a platform for funding, collaborative research, planning and development of public health programs.

Abbreviations

PTA-MLL - Pretoria Medico-Legal Laboratory
LMIC - low to middle income countries
HIC - high income countries
COHb - carboxyhaemoglobin
BAC - blood alcohol concentration
TBSA - total body surface area
ARDS - acute respiratory distress syndrome
AKI - acute kidney injury

Keywords: Burn fatalities, Pathology, Post mortem, Forensic, Autopsy, Demographics

1. Introduction

Burn fatalities, despite being preventable, contribute significantly to the global burden of injury [[1], [2], [3], [4]]. These fatalities occur in developing countries, where resources are limited or redirected to communicable and non-communicable diseases such as HIV/AIDS, tuberculosis and diabetes mellitus (DM) [[4], [5], [6]].

There is scant literature surrounding the extent, risks and costs associated with burn fatalities in South Africa and other low to middle income countries (LMIC) [7]. Published South African research into burn fatalities has emanated chiefly from Cape Town and Johannesburg. These studies have focused on in-hospital fatalities, fatalities in specialised burns centres and on children [7,8]. In 2011 Allorto et al. estimated the total cost of managing a patient with 3rd degree burns involving 20% total body surface area (TBSA) to be between ZAR103,000–ZAR154,000 (approximately $7000–$11,000) [9].

Reasons for high burn fatalities in LMIC's are multifactorial and include alcohol abuse, poor socio-economic status and lack of basic safety education [1,2]. Shacks are primary dwellings in informal settlements and are typically built from highly flammable materials [8,10,11]. Informal settlements are usually poorly accessible, over-crowded, lack access to running water, lack co-ordinated emergency services and often have illegal electricity connections [[10], [11], [12], [13]]. The use of cheaper alternative sources of energy including paraffin stoves (primus stoves), open flames or fires and candles is not uncommon in informal settlements [9,14,15].

Mortuary-based studies have been published by Blom et al. [8] and Sukhai et al. [16], from Mpumalanga and KwaZulu Natal Provinces in South Africa. These studies used the National Injury Mortality Surveillance System (NIMSS) data collection sheets as their primary sources of data and not specific case files or post mortem reports [[7], [8], [9]].

Autopsy findings in burn fatalities are highly variable and depend on the cause of injury, duration of exposure and temperature of the heat source and on whether the death was immediate or delayed [[17], [18], [19]]. The cause and mechanism of death is not always apparent and in such cases oxygen deficiency, inhalation heat shock, acute or primary shock and laryngospasm should be considered [17,[19], [20], [21]]. Delayed death in burn injuries may be due to a wide range of complications including those involving the respiratory system, multiple organ failure, sepsis and burn shock [6,[22], [23], [24]]. Currently, septicaemia remains the most common mechanism of death in burn fatalities occurring in South Africa and other LMIC's [6].

Pretoria is the capital of South Africa (RSA), situated in the Tshwane metropolitan region, with 92.3% urbanisation. The Pretoria Medico-Legal Laboratory (PTA MLL) serves the greater part of this urban population. Based on the 2011 census, Tshwane has a population of 2, 921, 488 million of which 2.2 million (75.4%) are black and approximately 600,000 (20.1%) are Caucasian. More than 75% of the Tshwane population resides in formal housing and 72.2% of households have access to electricity. Sanitation and running water are available in 77.9% and 87% of all households respectively. Tshwane has a near equal split of males and females at 49.8% and 50.2% respectively. Children between 0–4 years constitute 9.4% of the Tshwane population [25].

The study had two aims: (i) to describe the demographic profile and (ii) autopsy findings in burn fatalities admitted to the PTA MLL in South Africa over a 5-year period from January 2011 to December 2015.

2. Materials and method

Prior clearance was obtained from the University of Pretoria's Faculty of health Sciences Research Ethics Committee (reference number 01/2017).

This was a retrospective descriptive study of all burn fatalities admitted to the PTA MLL for the five-year period from January 2011 to December 2015. The study was conducted at the PTA MLL a facility of the Gauteng Department of Health and at the Department of Forensic Medicine, University of Pretoria.

The following inclusion criteria were applied:

- All fatalities admitted to the PTA MLL from January 2011 to December 2015 as burns irrespective of age, race, gender and place of death.
- Fatalities associated with explosions where burns were deemed to be the primary cause of death.

The following exclusion criteria were applied:

- Burns due to chemicals, lightning, radiation, friction and electricity.
- Decomposed bodies and skeletonized remains, even if burns may have been suspected.
- Stillbirths and non-viable foetuses which may have been due to burns.
- Fatalities in which burn injuries are present but are not the primary medical cause of death.

Data was collected from the PTA MLL case files including the post mortem report, toxicology results and medical summaries (hospital fatalities only).

The following variables were recorded: demographic profile, date and time of death, circumstances of the burn injury, place of injury and death, apparent manner of death, mechanism of death, pathology of burns and related complications, special investigations (histology and toxicology) and methods used to establish identity.

The data was anonymised. Epi-info™, Microsoft Excel and the Stata 14 computer software program were used for data storage and analysis.

3. Results

A total of 9558 bodies were admitted to the PTA MLL in terms of the Inquests Act 58, 1959 (Act No. 58 of 1959) during the 5-year study period [Table 1 shows the number of bodies admitted at the PTA MLL per year]. These deaths were deemed to be unnatural as stipulated in the National Health Act 61, 2003 (Act No.61 of 2003) R. 916. Regulations Regarding the Rendering of Forensic Pathology Service, 2017. Of the 9558 deaths, 291 (3%) met the inclusion criteria for this study and were deemed to be due to burns.

Table 1 – Shows the number of bodies admitted at the PTA MLL and number of burn fatalities per year.

Year	Number of fatalities per year (n = 9558)	Number of burn fatalities per year (n = 291)	Percentage of burn fatalities per year (%)
2011	2037	69	3.4%
2012	1919	69	3.6%
2013	1817	54	3.0%
2014	1862	56	3.0%
2015	1923	43	2.2%
Total	9558	291	3%

3.1. Demographic profile

Of a total of 291 fatalities, 249 (85.6%) were black and 30 (10.3) white [see Table 2]. Two hundred and fourteen (73.5%) decedents were male and 75 (25.8%) were female [see Table 3]. The male:female ratio was 2.9:1. The mean age was 33.4 years and the range of 0–89 years. In each individual age group, most of the decedents were male except in the 10–14- and 15–19-years age groups where females constituted 75% and 50% respectively. Most of the fatalities occurred in the 0–4 years age group which constituted 14.5% of the cases [see Fig. 1]. Age was unknown in 8 fatalities.

Table 2 – Race distribution of burn fatalities over the five-year period from 2011–2015.

Race	Number of burn fatalities (n = 291)	Percentage
Black	249	85.6%
White	30	10.3%
Indian	2	0.7%
Coloured	5	1.7%
Unknown	5	1.7%
Total	291	100%

Table 3 – Gender distribution of burn fatalities over the five-year period from 2011 to 2015.

Gender	Number (n = 291)	Percentage
Male	214	73.5%
Female	75	25.8%
Unknown	2	0.7%
Total	291	100%

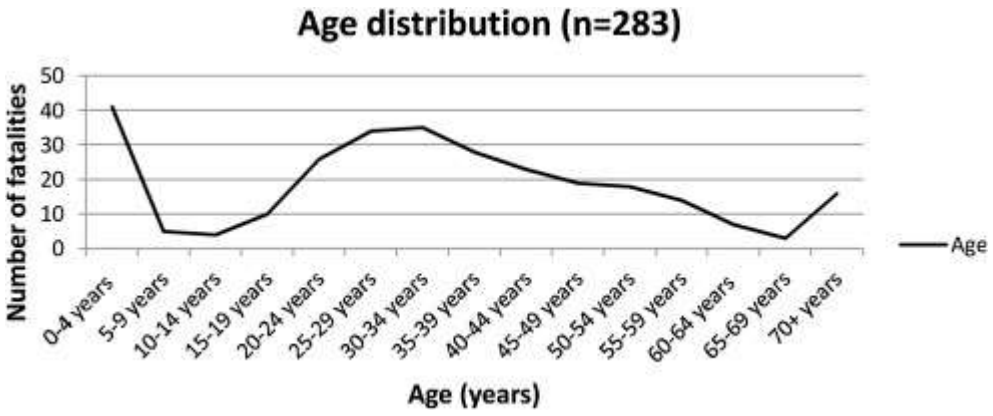

Fig. 1. Shows the age distribution of all burn fatalities over the 5-year period from 2011 to 2015.

3.2. Manner of death

The most common manner of death as assessed by the forensic pathologist/medical practitioner at the time of the autopsy irrespective of race, gender and location of injury was accidents at 203 (69.8%). Please note that the assessment was based on the information

available at the time of the autopsy and does not constitute a formal legal finding. Twenty-three fatalities (7.9%) were deemed to be homicides and 11 (3.8%) as suicides. In 54 (18.5%) of the fatalities the manner of death was unknown. Of the 11 suicides, nine (81.8%) occurred in males and 2 (18.2%) occurred in females with a male:female ratio of 4.5:1. The majority of homicides occurred between the ages of 40–44 years.

3.3. Circumstance of injury

One hundred and fifty-four (52.9%) fatalities occurred at the scene of injury and 137 (47.1%) occurred in hospitals. Of the 137 fatalities occurring in hospitals, 111 (81.0%) cases were from the public health sector and 26 (18.9%) cases were from the private health sector. Fourteen (10.3%), 30 (22.1%) and 67 (49.3%) of fatalities that occurred in the public health sector were from primary, tertiary and quaternary hospitals, respectively.

Open flame/fire fatalities accounted for 255 (87.6%) of cases, hot liquid burns/scalds 24 (8.3%) and explosions 11 (3.8%). In 1 (0.3%) fatality the circumstance of injury was unknown. Open flame/fires were the most common cause of burn fatalities in all age groups including children between the ages of 0–4 years. Some of the common causes of open flames/fires included candles, motor vehicle accidents and primus (paraffin) stoves.

Most of the fatalities occurred in June, July, August and September which are the coldest months of the year in South Africa and are associated with increased energy/electricity consumption see Fig. 2.

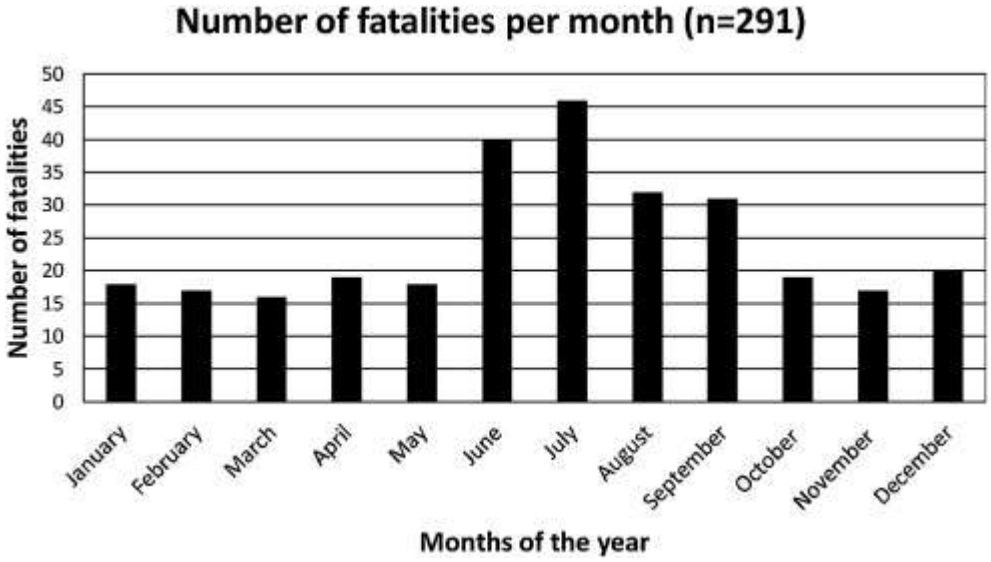

Fig. 2. Shows the number of fatalities per month over the 5- year period from 2011 to 2015.

3.4. Place of death

Of the 291 fatalities, more than one fatality (in other words, multiple fatalities), was reported in 32 (11%) incidents. Of the 291 fatalities, 152 (52.2%) occurred indoors, 46 (15.8%) outdoors and in 93 (32.0%) the location of injury was unknown. Of the 152 cases where death occurred indoors, 105 (69.0%) occurred in informal dwellings (shacks) and 26 (17.1%)

in formal dwellings (brick houses). Of the 105 fatalities that occurred in a shack, more than one fatality (in other words, multiple fatalities) was reported in 15 (14.3%) of the incidents.

Regarding those who died on the scene, 150 of the 154 were as a result of open flames/fires, three (1.9%) hot liquids/scalds and one (0.7%) was due to an explosion.

Regarding those admitted to hospital, open flames/fires were responsible for 105 (76.6%) of the 137 fatalities, 21 (15.3%) due to hot liquids and 10 (7.3%) due to explosions. The mean length of hospital stay was 12.4 days and the range 1–138 days. The mean length of Intensive care unit (ICU) stay was 8.5 days and the range 1–125 days. Of the 137 fatalities, 83 (60.6%) were admitted into ICU. Forty-five (32.8%) of the 137 fatalities occurred within the first 24 h of admission.

3.5. Pathology of burns

Of those who were declared dead at the scene, the mean total body surface area was 92.0% with a range of 35–100%. In 142 (92.2%) of fatalities, the decedents were charred beyond recognition.

Of those who were declared dead in hospital, the mean total body surface area (TBSA) was 58.9% and the range 5–100%. The most common degree of burns in hospital fatalities irrespective of type of burn was the 3rd degree burn.

Table 4 shows heat artefacts that were noted in cases of open flame/fire and explosion fatalities occurring at the scene of injury. Heat coagulation and pugilistic attitude were noted in most of the fatalities.

Table 4 – Represents heat artefacts identified in open flame/fire and explosion fatalities occurring at the scene of injury.

Heat artefacts identified in fatalities occurring at the scene of injury	Number (N = 154)	Percentage (%)
Calcined bone	27	17.5%
Charred organs	45	29.2%
Epidural heat haematoma	39	25.3%
Exposed body cavities	65	42.2%
Heat fractures	77	50.0%
Heat coagulated internal organs	104	67.5%
Leathery coagulation of the skin	30	19.5%
Loss of extremities	52	33.8%
Tongue protrusion	47	30.5%
Pugilistic attitude	108	70.1%
Skin blisters	22	14.3%
Skin splittage	55	35.7%
Singed hair	47	30.5%

3.5.1. Scene fatalities: signs of vitality

In 122 (79.2%) of 154 fatalities, soot deposition was noted in the upper and lower airways. Soot was noted in the oesophagus of 60 (38.9%) and stomach of 14 (9.1%) of scene fatalities. Mucosal hyperaemia, oedema and blanching were noted in 33 (21.4%), 23 (14.9%) and 33 (21.4%) of scene fatalities respectively. Cherry-pink discolouration of blood, viscera and soft tissues as recorded in the autopsy report was noted in 114 (74.0%) of fatalities. In 104 (67.5%) of scene fatalities, cherry-pink discolouration (blood, viscera and soft tissues) and soot deposition in the airways were noted. Table 5 shows signs of vitality that were noted in fatalities that took place at the scene of injury where the external cause of injury was open flames/fires and explosions.

Table 5 – Shows signs of vitality that were noted in fatalities that took place at the scene of injury where the external cause of injury was open flames/fires and explosions.

Signs of vitality	Number of fatalities (n = 154)	Percentage (%)
Airway mucosal blanching	33	21.4%
Airway mucosal hyperaemia	33	21.4%
Airway mucosal oedema	23	14.9%
Soot deposition: upper airway	129	83.7%
Soot deposition: lower airway	123	79.8%
Soot deposition: oesophagus	60	38.9%
Soot deposition: stomach	14	9.1%
Cherry-pink discolouration: blood, viscera and soft tissues	114	74.0%

3.5.2. Hospital fatalities: airway mucosal injuries

Features consistent with airway mucosal injury such as mucosal hyperaemia and oedema were noted in 39 (28.5%) and 38 (27.7%) of fatalities respectively. Soot was noted in the airways of 29 (21.3%) hospital fatalities. Of the 45 hospital fatalities occurring within 24 h of the incident, airway mucosal injury was noted in 22 (48.9%) and soot deposition in 15 (33.3%) fatalities.

3.5.3. Hospital fatalities: pulmonary and other complications

Pulmonary complications were the most common type of complication in hospital fatalities. Table 6 provides a list of complications that developed in decedents admitted to hospital as recorded in the autopsy reports.

Table 6 – Represents a list of all complications that were noted in burn fatalities that occurred in hospitalised burn victims irrespective of the type of burn.

Complications of burn injuries in hospital fatalities	Number (n = 137)	Percentage (%)
Pneumonia	58	42.3%
Pleural effusion	44	32.1%
Wound sepsis	38	27.7%
Features of acute respiratory distress syndrome (ARDS)	35	25.5%
Features of acute kidney injury (AKI)	28	20.4%
Peritoneal effusion	22	16.1%
Pericardial effusion	17	12.4%
Gastric ulcers (Curling ulcers)	12	8.8%

3.5.4. Airway mucosal injuries and soot deposition in scene and hospital fatalities

Of the 291 fatalities, mucosal oedema was noted in the airways of 61 (20.9%) and mucosal hyperaemia in 72 (24.7%) of all fatalities. Soot deposition was noted in the airways of 150 (51.6%) of all fatalities.

3.6. Identification

Of the 154 scene fatalities, facial identification was possible in 12 (7.8%) cases. Of the 142 (92.2%) charred bodies, identity was confirmed in 134 (94.4%) fatalities. In 42 (31.3%) of the 134 fatalities, the method used to confirm identity was not specified in our data sources. Specimens for DNA analysis were collected in 103 (76.9%) of the 134 fatalities. DNA results were positive in 27 (26.2%) of the 103 fatalities. Methods used to confirm identity in 92 fatalities were: sworn statements from witnesses in 59 (61.4%) of fatalities, DNA analysis in 27 (29.3%), dental identification 4 (4.3%), finger prints 1 (1.1%) and special identifying features in 1 (1.1%) of cases.

3.7. Special investigations

3.7.1. Toxicology

Of the 291 cases, toxicological analyses were performed in 181 (62.2%) cases and in 51 (28.1%) of these, results were pending at the time of the study. Of the 181 fatalities, blood for alcohol was collected in 168 (57.7%) and results were available for 122 (72.6%) of these fatalities [see Fig. 3]. The mean blood alcohol concentration (BAC) was 0.09 g/100 ml and the range was 0–0.33 g/100 ml.

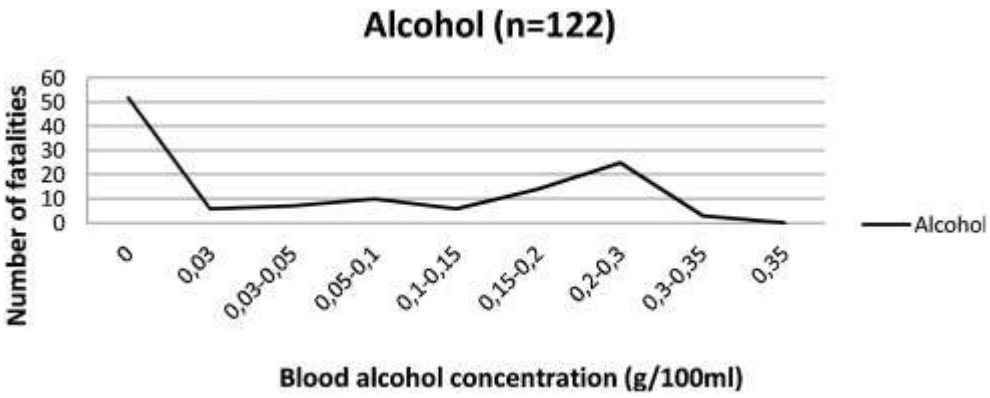

Fig. 3. Shows blood alcohol concentrations where the results were available.

In 154 of the scene fatalities, toxicology was collected in 147 (95.5%) fatalities. Of the 147 fatalities, toxicological results were available in 104 (70.7%). The mean BAC in scene fatalities was 0.11 g/100 ml and the range 0–0.33 g/100 ml. The mean BAC in shack fatalities was 0.14 g/100 ml and range the 0.0–0.32 g/100 ml.

Blood for carboxyhaemoglobin (COHb) was collected in 169 (58.1%) of all fatalities. Of the 169 fatalities in which blood for COHb was collected, results were available for 121 (71.6%) fatalities. In 64 (52.9%) of the 121 fatalities, COHb levels were elevated (above 10%). In 16 (25%) of the 64 fatalities, COHb levels were above 40% [see Fig. 4]. The mean blood COHb level was 19.9% and the range was 0–76.1%. Cherry pink discolouration and soot deposition in the airway were noted in all fatalities in which COHb levels were above 40%.

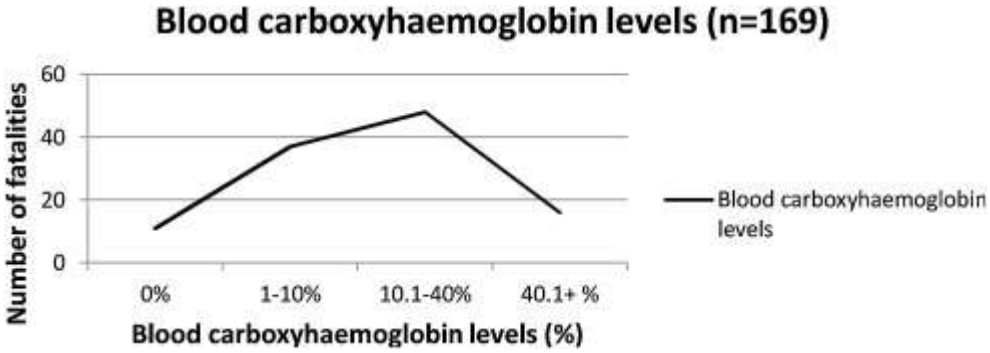

Fig. 4. Shows blood carboxyhaemoglobin levels in fatalities in which the results were available.

The mean COHb in shack fatalities was 23.9% and range the 0–76.1%. The mean COHb in hospital fatalities in which death occurred within 24 h of the incident was 3.07% and the range 0–10.9%.

Blood for cyanide testing was collected in 80 (27.5%) of all fatalities. The laboratory reported not being able to test for cyanide levels in 20 (25.0%) of the specimens sent for analysis. All available cyanide results 53 (66.3%) were reported as negative.

4. Discussion

This study reviewed 291 burn fatalities admitted to an urban mortuary, the PTA-MLL. Over the 5-year study period approximately 3% of the fatalities at this mortuary were as a result of burns occurring at a rate of approximately 1 fatality per week. Over the 5-year study period the number of cases declined gradually from 69 per year to 43 per year.

This study showed a male predominance throughout all age groups with an overall male:female ratio of 2.9:1 which is higher than the mean global male:female ratio of 1.92:1 [1]. Globally, burn fatalities are more common in adult males except in the South Eastern regions of Asia and Eastern parts of the Mediterranean region where the opposite applies [2,26].

The highest number of burn fatalities were in young children between the ages of 0–4 years. This is a significant finding which requires attention. The 2010 and 2011 Gauteng NIMSS report identified burns as the most common cause of unnatural deaths in children between 0–4 years [27,28]. This study was performed more than five years after the NIMSS report and many children within this age group were still dying as a result of burns, which warrants further investigation.

The median age of burn fatalities at the PTA MLL was 33.4 years which was higher than Sub-Saharan countries with a mean of 15.3 year but lower than HIC's like the Netherlands with mean ages of 58.2 years and 63.5 years [4,22,29]. This implies burn fatalities in LMIC's occur in the economically active group of the society, perpetuating the poor socio-economic status.

Whilst we cannot confirm the precise number of shacks in this area, we can state that the number of shack fires is probably underrepresented as detailed information on this type of dwelling was not available. These findings correspond with previous South African studies [7,10,11]. Pretoria is predominantly urban with more than 75% of the population residing in formal housing [25]. It is concerning that more than two thirds of indoor fatalities in occurred in shack fires.

The high number of accidental burn fatalities at the PTA MLL corresponds with international findings [2]. Self-immolation is relatively uncommon except in countries such as India and Northern Tunisia [26,30]. In India, self-immolation was more common in females while the opposite applied to Northern Tunisia [29,33,34]. In this study, self-immolation was more common in males with a male:female ratio of 4.5:1 which corresponds with findings from other African countries and different regions of South Africa [26,30].

In Pretoria homicides made up 7.9% of burn fatalities which were higher than the Western Cape and KwaZulu Natal, and lower than Mpumalanga [7,8]. Homicidal burn fatalities were uncommon in HIC's such as the United States, Europe and Japan [1,32]. Two separate studies conducted in Germany had homicide burn rates of 14.8% and 6%, respectively (20–21). Australia had a homicide burn rate of 9% [32]. The age and gender profile of homicides in Pretoria were similar to global findings [[1], [2], [3]].

In delayed fatalities, pulmonary complications such as pneumonia, ARDS and pleural effusions, acute kidney injury and wounds sepsis were common which corresponds with

international findings [22,29]. Sepsis remained the most common complication in LMIC's, such as India and other Sub-Saharan regions of Africa [4,6,31].

Cherry-pink discolouration of tissues was noted in all scene fatalities in which COHb levels were above 40%. In this study, soot was reported in the airways of cases where cherry-pink discolouration and COHb levels were above 40%. A relationship exists between cherry-pink discolouration and levels of COHb but not between soot deposition and cherry-pink discolouration or soot deposition with levels of COHb [20,21]. The presence of these vital signs is consistent with peri-mortem respiratory efforts during the time of the fire [20,21].

At our facility cyanide levels were reported as negative in two thirds of cases where analysis was conducted. These findings do not exclude cyanide toxicity as various factors such as storage temperature, time between sampling and testing may result in errors [33,34]. These findings were of concern, considering the time lapse between collection of the specimen and receiving results. A review article by Anseeuw et al. [35] documented that cyanide results varied depending on the study. Elevated levels of cyanide were detected in all but one article which were reviewed in the literature [35].

Blood alcohol concentrations were tested in all burn fatalities except children, or where blood could not be obtained for various reasons, or in cases of prolonged hospitalisation. The mean BAC was 0.09 g/100 ml for all fatalities. The mean BAC was 0.11 g/100 ml in scene fatalities and 0.14 g/100 ml in fatalities occurring in shack fires. These findings are in-keeping with previous studies that identified alcohol as a risk factor for burn fatalities in HIC's and LMIC's [1,2,12]. These findings were high, considering that in South African (RSA) the legal limit for alcohol intoxication is 0.05 g/100 ml as stipulated in the National Road Traffic Act 93, 1996 (Act No. 93 of 1996).

5. Limitations

Limitations to the study included: incomplete and/or lacking medical reports and outstanding toxicology results as well as changes in geographical jurisdictions which influenced the number of unnatural deaths admitted to the facility.

6. Conclusion

This study has shown that burn admissions were relatively common at the PTA MLL presenting at a rate of approximately 1 fatality per week, although burn fatalities gradually decreased within the 5-year study period. Children between the ages 0–4 years were at risk for burn fatalities. Self-immolation was more common in males than females. More than two thirds of fatalities occurred indoors, chiefly in shacks. Features consistent with peri-mortem respiration were noted in many of the scene fatalities. Pulmonary complications were common in the delayed (hospital) deaths. The mean BAC's was high, especially in shack fires.

Cyanide toxicity may be underestimated due to a delay between collection of the specimen and analysis.

The study represents the first of its kind in South Africa to generate bimodal (in-hospital and scene fatalities) descriptive statistics for burn fatalities. This data may provide a platform for

improved funding, collaborative research and aid in the planning and development of public health programs.

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Conflict of Interest

The authors declare no conflict of interest.

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