DEATH BY ELECTROCUTION:

A RETROSPECTIVE ANALYSIS OF THREE MEDICO-LEGAL MORTUARIES IN THE eTHEKWINI DISTRICT OF KWAZULU NATAL FROM 2006 TO 2016.

A Study Project presented to the Division of Forensic Medicine and Toxicology of the University of Cape Town

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DECLARATION

I, Anez Awath-Behari, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor part of it has been, is being, or is to be submitted for another degree in this or any other university.

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Glossary of Terms

Cause of death: **"**The disease, condition or injury that leads directly or indirectly, immediately or subsequently to death**."***

Mechanism of death: **"**The physiological derangement or biochemical disturbance produced by the cause of death."*

Manner of death: **"**The circumstances of how the death arose e.g., homicide by gunshot**."***

Negative autopsy: An autopsy where all protocol efforts fail to reveal a cause of death.Ω

Informal settlements: **"**Unplanned settlements and areas where housing is not in compliance with current planning and building regulations (unauthorised housing)."¥

BI-1663-death notification: *"*The DHA-1663 is a death notification form issued by the attending medical practitioner for registering the death at the Department of Home Affairs for an official death certificate. This form is not a death declaration; therefore, it cannot be used as an alternative to the death declaration or 'dead on arrival' forms.''©

***** Dada MA, McQuoid-Mason DJ. Introduction to Medico-legal Practice. Durban: Butterworths, 2001.

Ω Cohle SD, Sampson BA. The negative autopsy: sudden cardiac death or other? *Cardiovasc Pathol*. 2001;10(5):219-222. doi:10.1016/s1054-8807(01)00093-x

¥ Glossary of Environment Statistics, Studies in Methods, Series F, No. 67, United Nations, New York, 1997.'

©http://www.westerncape.gov.za/assets/departments/health/h1462020__admission_requirements_of_decedents_of_unnatural_causes.pdf

Abbreviations & Words Unique to this Dissertation

SAPS	SOUTH AFRICAN POLICE SERVICES
WHO	WORLD HEALTH ORGANISATION
FPS	FORENSIC PATHOLOGY SERVICE
ESKOM	ELEKTRISITEITSVOORSIEINGSKOMMISSIE(translated Electricity Supply Commission)
PRASA	PASSENGER RAIL AGENCY OF SOUTH AFRICA
ICD	INTERNATIONAL CLASSIFICATION OF DISEASE
RDP	RECONSTRUCTION AND DEVELOPMENT PROGRAMME
NIMSS	NATIONAL INJURY MORTALITY SURVEILLANCE SYSTEM
BAC	BLOOD ALCOHOL CONCENTRATION
JHB	JOHANNESBURG (CITY IN SOUTH AFRICA)
DOA	DEATH ON ADMISISON
V	VOLTAGE
LV	LOW VOLTAGE
HV	HIGH VOLTAGE
A	AMPERAGE

ABSTRACT

Background: Electrocution is a well-documented cause of unnatural death globally. Identification of demographic and spatial trends in developed countries has assisted in highlighting contributing factors and identifying areas at risk. This information and the appropriate institution of changes have proven worthwhile in reducing fatalities internationally. Less developed countries have shown increasing trends in electrocution fatalities related to rural-urban migration and growing electricity demand. Additional challenges plaguing such countries include illegal electricity connections and load shedding. The association of such issues to electrocution deaths have been sparsely explored. There remains a paucity of information regarding electrocution fatalities in South Africa and Africa as a whole. A general trend of increasing electrocution fatalities referred for medico-legal autopsy was observed at three medico-legal mortuaries in the eThekwini district of Kwa Zulu Natal, South Africa, from 2006 to 2016.

Objectives This study aimed to analyse the epidemiology, characteristics and trends of deaths resulting from electrocutions.

Methods. A retrospective descriptive study was conducted. Fatal non-lightning electrocutions autopsied at three medico-legal mortuaries in the eThekwini district over an 11year period, from 1st January 2006 to 31st December 2016, were analysed. Data sources included clinician notes, emergency services documentation, scene scripts including South African Police Services(SAPS) 180 form completed by SAPS representatives, postmortem and histology reports, toxicology reports from Forensic Toxicology unit, contemporaneous notes, postmortem death registers, daily listings of postmortem case allocations and electronic postmortem databases. Data were collated and categorised on an Excel spreadsheet and then analysed on statistical package STATA 13 (Stata Corp, TX, USA).

Results: There were 512 non-lightning electrocution fatalities from 1st January 2006 to 31st December 2016. The trend of electrocutions indicates a general increase in cases from 2006, reaching a peak in 2013 followed by a gradual decrease until 2016. Most fatal electrocutions occurred in domestic environments amongst males in the third and fourth decade of life. However, a bimodal distribution showed a considerable number of electrocutions under 10 years of age, predominantly amongst females. The largest number of electrocutions were admitted to the chief medico-legal mortuary servicing the metro, Gale Street mortuary (43,95%). However, the highest concentration of cases was observed in Tongaat, a suburb on the outskirts of the metro. This contributed to the highest prevalence of electrocution cases (1,25% of all electrocution cases) being admitted to the Phoenix medico-legal mortuary, which serves predominantly Northern eThekwini, including Tongaat, and which lies on the fringe of the metro.

Deaths from electrocution tend to occur mainly during the midday period, during the weekends, and commonly during the summer months. Injuries associated with fatal electrocutions in all age groups studied generally affected the extremities and predominantly involved the upper limbs. Blood alcohol concentrations were established in just over a quarter of cases and were mostly negative.

Conclusion: Electrocution is an easily preventable unnatural death that remains poorly documented and analysed, especially in developing countries, with a paucity of studies in South Africa. Preventative measures and protocols cannot be generalised amongst populations. An appreciation of the demographic and temporal trends of electrocutions is crucial in order to institute preventative policy.

CHAPTER 1

Introduction

1.1 Background

Electricity continues to impact our daily lives with increasing frequency. Internationally, electrocutions have been documented amongst the top five leading causes of occupation-related deaths.[1] Studies conducted both internationally and nationally iterate that the victims are predominantly adult males, the manner of death is mainly accidental and such deaths are easily preventable.[2] Incidence rates reflected in literature are influenced by factors such as the population density and profile,[3,4,5] the access to electricity, [3,4,11,] the sector investigating or documenting electrocutions (viz occupational, military, forensic, domestic),[3,4, 7,8,9,10,11] period of study and inclusion criteria,[3,4,6] implementation and monitoring of prevention, and death classification.[6,7,8] The variability of these factors and inconsistencies in sampling between study populations may lead to overestimating or undermining electrocution statistics. Stringent monitoring and reporting demanded in the occupational sector may lead to a bolstering of overall electrocution fatality statistics. [3-11] Notification of electrocutions deaths by forensic pathologists is a formidable tool in collating mortality statistics, identifying trends, creating awareness, monitoring prevention programmes and contributing to public health. [12]

The electrocution fatality presents one of the most challenging cases to the forensic pathologist. [12,-20] An appreciation of the physical properties of electricity is an essential primer to the autopsy approach of such victims.

Electricity is the flow of electrons through a conductor, across a potential gradient.[12-20] The conductor completes a circuit for electron flow from a source of electrons to the earth. Electrocution results when an individual completes the circuit, either by direct contact with current or via an intermediary such as metal. Electrocution occurs following the simultaneous interaction of a triad; the charged electrical source, passage of electric current through an individual and a

ground (which has the same electrical potential as the earth, or zero, and which in electrocution victims, is commonly the foot.). [15,16,17] Electrocution need not necessarily be lethal, however the derivation of the word from "electricity" and execution" attests to its recognised capacity to do so.[16]

Electrical injury is determined by current (volume of electrons that flow along the gradient; I) voltage (force that drives the electrons; V) and resistance (impedence of electron flow;R). Current is the most important factor in electrocution. However, the interaction of the three parameters is what ultimately determines the effect of electricity in relation to the human body, and is exemplified in Ohm's Law, where I=V/R [12-20]

The application of Ohm's Law is appreciated in a forensic setting where a body that is wet is likely to exhibit minimal or no external injuries. The surface moisture offers less resistance allowing current to flow with ease and thereby causing more internal damage. As a result, minor external injuries or the absence thereof, is no reflection of the degree of internal electrical injury. Internal resistance to varying current density may be appreciated at the cross sectional area of tissue; a joint is composed of more tissue of a higher resistance, than that of blood vessels. Consequently, a current travelling through a joint tends to concentrate its low resistant components in comparison to the more diffuse arrangement in blood vessels, explaining why joints are particularly prone to injury throughout the body [12-20]

Voltage has been characterised as either low (<1000V) or high voltage (>1000V) in studies.[1]High voltages are usually associated with significant injuries, occur primarily in the occupational sector,[1] and need not require direct contact with a subject for electrocution to occur.[1]Low voltages commonly used in households, have been associated with domestic electrocutions, often due to working with faulty appliances or wiring (up to32%), and requires direct contact with the individual.[1]The South African household is typically provided with 240Vof alternating current.[24]

The effects of electricity on the human body include cellular depolarisation of muscles and nerves ultimately affecting membrane potential, and thermal effects.[17]

The degree of electrical injury in individual cases may be determined by the pathway through the body (transthoracic is considered more dangerous due to passage through the heart), type of current (alternating current is more dangerous), amplitude of current, duration of exposure to current, amount of voltage and the surface area (where current density is inversely proportional to contact area).[12-20]

The forensic pathologist is tasked with establishing whether the circumstances of death and the injuries seen, indeed corroborate with electrocution as the cause of death. In some cases, this is evident as a plethora of documented lesions that may actually be a tell-tale sign of current pathway through the body. There may be a linear abrasion in the shape of the conductor. Spark lesions may occur where the current jumps from the conductor to the skin , melts the keratin and appears as a small raised nodule. The described typical "Joule burn" is evidenced by a collapsed blister with a pale raised edge and umbilicated centre. There may be an areolar of redness outside the lesion with associated blanching. Alternatively, minimal injuries with no reddening may be observed especially in hidden areas such as beneath contracted fingers. High voltages may be associated with extensive spark lesions which together resemble "crocodile skin"[12-20]

In many cases of electrocution, especially in that of low resistance or low voltage, there may be no injuries. Pathways through the heart resulting in arrythmias, or those that involve the respiratory muscles, may present as sudden unexpected deaths. There may be no indication of electrocution whatsoever, the only suggestion being that of a faulty electrical appliance following evaluation by engineers. Therefore, despite a warranted scene visit, thorough history and meticulous autopsy, electrocution continues to remain an elusive diagnosis in forensic pathology. [15-16]

Whilst electrical stigmata may be the most evident indication of the cause of death, literature documents that electrical burn marks can be formed post-mortem which can confound matters. Other signs, either noted macroscopically or by means of ancillary investigations, may be non specific[12-20] Dilemmas such as coexisting trauma or comorbidities pose as worthy competitors to electrocution in formulating the cause of death.[12,-20] Dokov proclaimed that the presence of electrocution stigmata does not necessarily imply that electrocution was the cause of death.[5]

In view of the often absent or non-specific pathology at post-mortem, forensic pathologists and scientists have looked towards other tools to strengthen or support death by electrocution.[18-20]These include histopathological and scanning electron microscopy features including those of skin vacuolisation, nuclear streaming and metallisation. Even then, the findings are not pathognomonic of electrocutions and have to be considered within the context of case history and findings. [18-20]

The mechanism of death in electrocution in most cases is largely attributed to ventricular fibrillation and has been held accountable for immediate death in up to 60 % of high voltage hand to hand pathway presentations. A low voltage household with a current of 60mA is enough to cause fibrillation whereas a current of less than 0,2mA may startle the individual enough to precipitate a fall from a height. There is no standardisation as to how to interpret such findings in the context of comorbidities.[15,16] Other mechanisms include respiratory paralysis and effects on neurological function, all of which leave no tangible signs at postmortem.[13,14] Non electrical mechanisms of death, including blunt force injuries from falls, have been well documented.[14]

The manner of death in electrocution is largely accidental. [1-20] Suicidal electrocutions have been described, and although considered uncommon, may be difficult to differentiate from accidental circumstances, particularly when they occur in water. Homicidal electrocutions have also been documented. [12,13,14] Torture by electrocution may present with no injuries on wet skin, or as a combination of both spark and contact wounds with movement.[14]

The reflection of electrocution fatalities in statistics and databases creates a further challenge in drawing attention to the magnitude of the problem. Electrocutions are often incorporated under the general umbrella of "burn''[21] or included with other causes ("exposure to electric current, radiation and extreme ambient air").[22]

Injury-related studies done nationally and provincially in South Africa poorly document the incidence of specifically electrocution, as a cause of death. Deaths and trauma due to electricity are often overshadowed by the more prevalent flame and scald burns. Discrepancies between statistics from various sources may, however, account for an overestimation or underestimation of this type of fatality.[23]

The regional context and demographic profile of the electrocution victim is a crucial starting point in identifying cases, recognising injuries and instituting targeted preventative measures for affected communities. African studies on electrocution and electrical burn mortality have recommended an investigation into high voltage deaths where as much as 31% of burn mortality cases were suspected of having been a result of cable theft or illegal connections.[24,25] International studies such as those in the United States, Ireland, and Italy, have documented electrocutions following cable theft as a rare cause of death, despite a reported clinical incidence of theft-related morbidity.[26-29] Comparatively, the incidence of cable theft has steadily increased in the eThekwini metro, Kwa Zulu Natal, from 446 reported incidents in 2006, 1 059 in 2007 to 1 914 in 2008. The Passenger Rail Agency of South Africa (PRASA) reported 668 cable theft incidents in Durban alone during 2016/2017. This is expected to rise further in response to increasing cable wire prices. There are no existing data to associate electrocution fatalities to cable theft in eThekwini, Kwa Zulu Natal, despite media reports to this effect.[30,31]

In South Africa, blackouts and load shedding have become common due to an acknowledged failure by national parastatal [Elektrisiteitsvoorsieningskommissie](translated Electricity Supply

Commission-ESKOM] to deal with increased demand.[32] Studies have shown that such interruptions can result in an increase in electrocution fatalities or, alternatively, lead to a reduction in electrocutions as individuals may resort to alternative forms of energy.[33]. Understanding trends related to electricity disruption may be crucial in instituting measures to diminish or prevent deaths resulting from this.

Despite the increasing use of electricity in daily lives, international experience has shown a decreasing mortality rate due to electrocution.[34] This has been attributed to an increased awareness of high-risk groups, appreciation of temporal and causal relationships, and the subsequent implementation of preventative measures.[35] Some studies show that the profile of such fatalities may vary with regards to where the deaths occurred, seasonal differences, and circumstances of death, amongst other factors.[35-37] Researchers concur that such a variety of temporal and behavioural differences in electricity use may account for varying degrees of electrical fatalities amongst nations and communities at risk. Appreciation of such differences is fundamental in order to implement targeted prevention. [35-37]This has been sparsely explored within the South African context.

The study aims to provide insight into the pattern, profiles and magnitude of death by electrocution in the eThekwini district, Kwa Zulu Natal. The study seeks to identify trends and potential risk factors with a view to implementing preventative measures. It is hoped that the study will improve the detection of the forensic pathological aspects of deaths resulting from electrocution. Such a foundation may be a useful platform to create awareness and directing prevention of such deaths.

1.2 Aims and objectives

Aims of the study:

- To determine the epidemiology, characteristics and trends of deaths resulting from electrocution seen at three medico-legal mortuaries in the eThekwini district over an 11year period, from 1st January 2006 to 31st December 2016.

Specific objectives:

1. To contextualise the value of forensic pathology in electrocution fatalities.

2. To determine the prevalence and trends of deaths ascribed to electrocution internationally and nationally.

3. To analyse the demographic and temporal profile of deaths by electrocution internationally and nationally based on age, sex , geographical , seasonal, and regional trends.

4. To analyse the forensic aspects of deaths by electrocution internationally and nationally in terms of anatomical distribution and spectrum of injuries, and ancillary investigations.

5. To determine obstacles that may be encountered in diagnosing deaths due to electrocutions.

6. To determine the prevalence of deaths ascribed to electrocution in the eThekwini district, Durban. KwaZulu Natal.

7. To analyse the demographic and temporal profile of deaths by electrocution in eThekwini district , Durban, KwaZulu Natal based on age, sex , geographical , seasonal and regional trends.

8. To analyse the forensic aspects of deaths by electrocution in eThekwini district, Durban, KwaZulu Natal, in terms of anatomical distribution and spectrum of injuries, and ancillary investigations including blood alcohol concentrations and histology.

9. To determine obstacles that may be encountered in diagnosing deaths due to electrocutions in eThekwini Durban , KwaZulu Natal and suggest areas for further study.

1.3 Chapter overview

Chapter 1 Introductory chapter to the background and need for the study.

Chapter 2 Literature review collates the available information, the current issues and trends facing pathologists regarding the diagnosis of electrocutions and areas of concern in the pathological entity.

Chapter 3 Methodology, data collection, analysis, and ethical considerations.

Chapter 4 Results of data collection in terms of demographic profiles and including schematic representation:

4.1 Prevalence of electrocution

4.2 Age of electrocution

4.3 Sex

Spatial and temporal profile including schematic representation

4.4 Geographic distribution

4.5 Month and season of the year.

4.6 Day of the week.

4.7 Time of day.

4.8 Anatomical distribution of injuries.

4.9 Illegal connections

CHAPTER 2

Literature review

Mortality databases such as those from the WHO indicate as much as a hundred times variance amongst European countries in the incidence of electrocution fatalities.[38] Morbidity and mortality rates from electrical injury range from 3-17%.[39,40]

In fact, the actual number of fatal electrocutions may be underestimated.[41]

A global review article of adult electrical injuries studies between 1946-2015 by Shih et al.[42] revealed 41 outcome-based studies; three coronial based studies with the rest being single institution based. The authors highlighted that the data from single institutions might result in an overrepresentation of electrocutions. Clinical studies described in the review documented higher mortality from high voltage compared to low voltage injuries (5,2% and 2,6%, respectively). However, coroners reported a 2,4:1 ratio favouring low voltages, suggesting that a greater number of low voltage injuries are associated with immediate deaths before hospitalisation.[42][Table 1]

In a retrospective coroner based study in Quebec Canada, Bailey et al showed that 92% of electrocution fatalities presented as immediate deaths or dead on arrival at hospital.[43] These were presumed to be as a result of arrythmia only in view of the time of death relative to exposure to electricity. This mechanism of death is widely accepted as a functional consequence of the properties related to electricity with no pathognomonic signs at autopsy.[12-20]The postmortem findings were consistent with electrocution only so far as the history or circumstance dictated on arrival at the hospital, or at the scene. The study confirmed the theoretical behaviour of electricity in the human body under expected conditions. [43] The study also demonstrated the challenging task of establishing electrocution as a probable cause of death, not only at the scene, but also at postmortem, especially in interpretation of other existing comorbidities. It is likely that such a cause may be underestimated unless there is full forensic examination, beginning

with a scene visit. As this may be not always be possible, the potential to underestimating such deaths is acknowledged.[43][Table1]

An Australian national injury surveillance unit indicated that electrocution fatalities might also be misreported.[44] The use of various databases and cross-referencing, particularly with coroners' reports, discovered five new cases of electrocutions previously reported as drowning or falls.[44] Interestingly, autopsy reports in a study in Lagos, Nigeria identified electrical burns as the most prevalent type of fatal burn. The actual number was not indicated. Many cases of electrocution were only identified at autopsy and highlights the importance of this tool to delineate specifically, electrocution related fatalities. The authors also attested that this number may be hugely underestimated due to the regional refusal to consent to autopsies.[45]From the observations above, it would appear that forensic pathology is an enviable catchment for such cases, the examination, understanding and reporting thereof.

Varying trends in electrocution fatalities have been documented by international countries. Nevertheless, autopsy based studies in Western and Eastern countries have demonstrated an overall decreasing trend in electrocutions, over varied time periods, despite an increase in use of electricity[46,49,50,5152,53,55] with regional fluctuations[47] or isolated peaks[49,53,55][Table1]

Encountered obstacles include attributing electrocution solely as a cause of death in the context of alternative, and equally relevant causes,[51]lack of standardisation of inclusion criteria for electrocution fatalities[48] and the overrepresentation of high voltage fatalities from hospital based referrals[54] which may result in a spurious reflection of electrocutions statistics.[50][Table 1]

In contrast , an Iranian study of electrocutions in the capital city Tehran, showed a progressive increase in electrocutions from 2002 to 2006 with an average annual rate of 0,7 per 100 000.[56]This exceeded the rates seen in all previous studies discussed,[43-55]some of which were conducted over longer periods.[44,47,50,51]

Within the South African context, Blumenthal conducted the first study on electrocution fatalities in Gauteng, the most populous province in South Africa, from 2001 to 2004 (n=126).[24.] Using both autopsy data and national injury surveillance data (NIMSS)*, the author concluded that electrocutions were a "serious problem.'' A sole autopsy based study (2010-2014) in Johannesburg , in that same province (Gauteng), however, demonstrated that electrocution fatalities were rare (n=28). Such fatalities accounted for 0,2% of all unnatural deaths at the mortuary with a mortality rate of 0,29.[57] Ironically. Johannesburg Forensic Pathology Service (FPS) is considered one of the busiest medicolegal services in the country. The study documented an overall decrease in electrical fatalities for the period, with isolated fluctuations, as experienced in other countries. [49,53,55] Von Caues observed electrocutions from 2008 to 2012 at Tygerberg's medico-legal facility in the Eastern Metropole of Cape Town, Western Cape, South Africa.[58] A total of thirty-nine fatalities electrocutions were analysed (0,5% of total 8351 unnatural deaths seen). The author agreed with the study above [57] that electrocutions were an uncommon cause of death in the serviced region.[57,58] The prevalence and trend of electrocutions in Kwa Zulu Natal is unknown.

Studies describe the quintessential electrocution fatality as a male of working age mainly in the third to fourth decade.[46-55]South African studies done on electrocution concur with these findings[27,57,58] Whilst some studies have solely considered adults,[42,47] others have commented on childhood fatalities,[43,46,48,-53,62,63] with some stratifying for electrocutions under 10 years of age.[48,49,56,,58,62]Specific isolation of this age group demonstrated that electrocutions were uncommon in an international dual country study (n=16) and were otherwise less common than adult electrocutions.[59] Two Turkish studies, however, individually highlighted that the highest number of electrocutions overall occurred in the 0-10 year category (30% of all electrocutions)[2], and that the 0-6years old were particularly vulnerable (20% of all childhood electrocutions, n=37) .[62]

In South Africa, age stratification for childhood electrocutions demonstrate no electrocutions in the under 20 years old in Johannesburg, to an "alarming burden in the under 10 years old in Cape town."[58] Cape Town also noted younger victims in general.[58.] Blumenthal noted that 41

* *The National Injury Mortality Surveillance System (NIMSS) est1999 provides more comprehensive information about deaths due to external causes. The information is collated from existing investigative procedures at (FPS) laboratories and state forensic chemistry laboratories: All unnatural deaths with an overview of how the different categories of causation For 2000, 15 FPS facilities in five provinces contributed data .

electrocutions (n=126) autopsied occurred under 25 years of age in Gauteng, although not specific to any district and with no disaggregation of childhood electrocutions.[24] Interestingly, other mortality studies in South Africa have identified childhood as being a high risk demographic for electrocution fatalities. [60] An autopsy study on all childhood and adolescent fatalities (0-20 years) from 2005 to 2009 in Pretoria, Gauteng, South Africa, showed that its highest number of electrocution fatalities (73%) occurred in the 1–5-year age group (8 out of 11 cases) with males predominating.[60.]

Matthews in an interprovincial pilot study on child mortality in 2014, demonstrated a greater number of electrocutions in the Phoenix mortuary (n=13), in eThekwini, KwaZulu Natal compared to the Salt River mortuary in Cape Town (n=4). Most of the childhood electrocutions were under 10 years of age.[61] Currently, there remains no explanation for the disparity in deaths. A 2007 NIMSS* report further illustrated that electrocutions in eThekwini were highest in the 1-4 year age group for that year with no electrocutions in this age group in Johannesburg.[62]

Electrocutions commonly occur in domestic environments.[46,-51,57] If data are disaggregated to reflect domestic and occupational trends, the following is noteworthy. Leisure related electrocutions exceeded occupational electrocutions despite a general decline in electrocutions overall.[48] The overall reduction in occupational related fatalities has largely been attributed to preventative and monitoring protocols.[7,8,10.]However, studies have demonstrated greater occupational fatalities, some despite these initiatives,[55,56] with a Johannesburg study showing no difference between the two sectors [58] Dokov also observed that whilst the typical victim profile was similar to those described in previous studies, the male to female ratio in the domestic circumstances were insignificant (1:17:1).[51] Kutic concluded that within a domestic environment, the bathroom was the most common place of electrocution in Croatia, especially amongst females, and amongst children.[49] It must be noted that due to lack of standardisation, leisure and work activities are not solely reserved for domestic or occupational environments, respectively. Furthermore, what may be crucial at the scene in investigating such fatalities, depended on the investigating authorities. Therefore, some studies were more comprehensive in including description of such environments. [49,51,58][Table 1]

The lack of standardisation in scene reports is further highlighted where some studies disaggregated environments into outdoor [47,55,56] or indoor[24,48,52,58] environments. Blumenthal made a distinction between indoors and outdoors related to voltages.[24] Low voltage electrocutions were more likely to occur indoors (78,4%) whilst high voltage occurred commonly outdoors (88,57%).This distinction was indicated at the scene on the South African Police Services (SAPS)180 form. Low voltage current is the primary source of electricity in the domestic setting.[52,58] and literature generally denotes an increased number of domestic or leisure electrocutions in association with low voltage current.[24,46-5], with the exception of low voltage being twice as likely to cause occupational fatalities in Croatia.[49] Ragui , however, observed that in Manipur, India, most electrocutions occurred outdoors, and were due to high tension wires (60% of all cases).though primarily occurring on roadsides (68%) [24,53][Table1]

Distinguishing between high and low voltage electrocutions appears to be an important factor in identifying place at risk for electrocutions and may be used as a proxy for amperage [14,46,] Whilst mortality rates appear greater in high voltages, they are relatively low in frequency. This may explain the predominance of low voltage electrocutions in literature.[49] Blumenthal noted differences in the prevalence of electrocutions on the basis of voltage that presented to medicolegal facilities.[24] In that study, Pretoria accounted for the most electrocution fatalities overall, including low voltage electrocutions. High voltage electrocutions (n=35) occurred mainly in Johannesburg, strengthening the case for this presentation in metros. There was no indication as to whether deaths were domestic or otherwise [24.] Ragui noted that 80% of deaths due to high voltage died immediately on the scene,[53]in contrast to predominantly low voltage in other studies.[42,43] Massey noted the need to differentiate voltage in each country as these may differ.[55]The Turkish study showed an equivalent number of high and low voltage electrocutions amongst all autopsied electrocution cases, with urban electrocutions dominating, occurring mainly in the workplace, and of high voltage.[50]The Johannesburg study also observed that electrocutions were concentrated mainly in the urban and suburban locations.[57.]In that study, only one case was identified in an informal settlement.

In comparison, Von Caues indicated that slightly more than half of electrocution cases occurred in Khayelitsha, one of the largest informal settlements in Cape Town.[58] Most deaths associated with illegal wiring and cable theft in that study, occurred in Khayelistha. Even though Von Caues did not stratify cases according to voltage as above, literature describes that injuries and deaths associated with such engagements, present as high voltage electrocutions.[24,25,57] Electrocutions caused by illegal wiring and cable theft have been well documented in South Africa.[24,25,57] but are not a unique national experience. Such associations have also been observed in Iran.[56]

When relating voltage to age, the Turkish study observed that low voltage fatalities were younger (52% in the second and third decade) than high voltage fatalities (third and fourth decade).[50]A striking observation was that all minor males in that study between 13-15years were electrocuted in high voltage incidents involving railways lines.[50] Childhood electrocutions although more commonly associated with domestic environments and low voltage, have not been exempt from high voltages.[59,61]Adolescents have been electrocuted in occupational environments, where regional child labour practices have been enforced.[62]

Circumstances in relation to electrocution largely include working with faulty electrical equipment, [47,48,51,53,58] not necessarily in occupational settings.[58] Some studies have also documented electrocutions associated with railway lines, often presenting as high voltage injuries[48,49,58] The relative incidence in literature is a reflection of the population sector under study.[48,-51]

Considering that most circumstances are related to daylight hours, it is not surprising that electrocutions commonly occur during the day. [24]

Blumenthal, however noted that high-voltage death were more likely to occur at night (18:00–00:00h) or in the early morning hours (0000–0600 h).[24] The author highlighted the contrast with literature which stated that high voltage deaths usually occur during the daylight hours. The author also concluded that the findings in Pretoria corroborated media reports, insinuating after-hour theft

or clandestine activities related to electricity utilities.[24] Such an observation has also been supported by findings in Cape Town.[58]

Seasonal variations in electrocutions show an increase in summer months [1,51,55] in the Northern hemisphere (June to August)[55] ;some studies attributed sweating , lowered skin resistance as well increased outdoor activity as risk factors during this time.[47,52,55] Studies in India have observed an increase in electrocutions related to the monsoon season (April to September).[61] This season characteristically coincides with the Indian summer, and accounted for 45% of the overall cases seen in one study.[61] Two studies, conducted in Gauteng , South Africa showed contrasting seasonal patterns in electrocutions related to summer and winter.[24,57] The study with electrocutions predominantly during South Africa's winter months (July and August) [57] attributed fatalities to the increased use of heating apparatus. The Cape Town study, however, concurred with other summer trends in electrocutions.[58]

With regards to the forensic investigation of electrocutions, the majority of electrocutions, whether of high or low voltage were unwitnessed (almost 87% under both condition) [24.]This contrasts a largely witnessed account amongst children (67,5%) where it was observed that 37,8% of children died instantly.[62]This concurs with the importance of history and a scene visit regarding electrocution fatalities.[12-20]

Whereas some studies have observed some sort of morphological electrical stigmata in most fatalities (79%),[49] the absence of external effects in electrocution cases have been well documented in literature and experience [24,52,56,] This has been particularly observed in low voltage injuries. [24]Wet extremities (16% , n=20) were present in 50% of those that died from household voltage in one study,[43] and, in all of the childhood victims with no injuries in another study[62.] Sweating was considered an important factor for the lack of external injuries seen in the low voltage electrocutions,[43,62] and has been emphasised in literature.[12-20]This factor may not be known or evident at postmortem, and unless a history of sweating or being wet is given, this may not be considered. The absence of external and often internal signs cements electrocution as an important

consideration in the "negative autopsy." However, in one study. 80% of electrical burns were attributed to have been caused by as a result of low skin resistance due to sweating.[55]

Th presentation at autopsy may be appreciated in the injuries primarily in anatomical sites related to active handling of electrical current sources, and its pathway through the body. Blumenthal personally designated these areas as the "chief anatomical site that demonstrated the most severe injury."[24] Notably in his study, those areas were the right and left hands (frequency of 30 and 17,respectively).[24] Literature establishes that the most common sites of injury in electrocutions are the upper limbs,[24,,49,50,55,57], specifically the right hand.[27,55,56] Other sites include the head [62] and the lastly, the foot.[57,62] Less commonly, both hands are affected.[58] The left hand was the most commonly involved in the Turkish study,[50] with the left foot also being more involved than the right.[50] The study in Johannesburg found no specific pattern to anatomical distribution but observed that the chest was the main affected area (57,1%), followed by right arm (50%). Joule burns have been documented primarily in relation to low voltage.[12-20,47] and have been observed in up to 93% of cases.[43,55,56] The Indian study documented that up to 82% demonstrated an entry wound only.[56] Both exit and entry wounds were documented in the Iranian study and the Croatian study (59,7% and 72% of cases, respectively).[56,49]

The study in Cape Town did not distinguish between entry and exit due to lack of information. However, the morphological appearance of wounds included descriptions such as crateriform, blistering and charring amongst others. The description lends itself to inconsistencies and observer bias without standardisation. [24,58] The author agreed with Blumenthal that formalisation of such descriptions are required.[24,58]

High voltages may present with non specific burns,[12,50,55] features of blunt force trauma due to falls,[27,58], limb amputations,[27], fat or gas embolism into the right ventricle [12] and singeing of the hair.[24] High voltage may have no burns,[24] or small superficial injuries.[12] Blistering has been documented in up to 21,98%. [24,58] The morphological findings are not mutually exclusive to the type of voltage; a "crocodile skin" appearance often associated with high voltages has been documented in low voltage electrocutions.[24] Overall, electrothermal injury was noted in 42% of Blumenthal's cases.[24] The presentation of collective features of burns, electrical stigmata and

blunt force injuries have been well documented in literature.[12-58] With the exception of Lindstrom[48], how conclusions are drawn as to the impact of individual factors in the cause of death have not been volunteered.

Children demonstrate the same anatomical distribution of injuries as adults with the right and left hands being the most commonly affected site. [62,63] An exception is that of perioral injuries relating to biting of electrical cords [62,63] Blunt force injuries including features such as subdural haemorrhage and vertebral fractures were documented in Ackan's study on childhood electrocutions. [63] · Other features include minor trauma such as contusions and abrasions.[62,63]The lack of such specific features allow for an overlap of presentations, including non accidental injuries in children.

Nonspecific general features also include congestion of organs [58]and petechial haemorrhages.[53] This has been acknowledged as is an important vital sign at postmortem.[52,53] in concordance with literature[12-20] Subendocardial haemorrhage, ventricular rupture and myocardial infarction have also been documented.[43]Due to limited documentation in studies, the overall contribution of such signs is speculative.

The pathway of current through the body is often unknown. Some authors regard the attribution of pathway in the mechanism of death in electrocution as contentious, especially in view of existing comorbidities such as cardiac disease.[42] Blumenthal nevertheless alluded a pathway through the chest in 58% of cases of low voltage with the least determined pathway postulated as through the head.[24] Elevated cardiac enzymes in individuals with a lack of coronary artery disease may support a pathway through the heart in electrocutions.[12]A pilot study in histological correlation with a history of electrocution has demonstrated cardiac interstitial microhaemorrhages to be more common in high voltage electrocutions, a finding that was limited by a small cohort.[64]

Histological features of electrocution have been documented as an adjunct in support of the cause of death. Extensive burns can make it difficult to differentiate between electrocution and thermal burns. Histological changes including intraepidermal and subepidermal separation, nuclear

palisading and metallisation for electrocution are nonspecific, may be found in thermal burns. and must be used in conjunction with the history and clinical findings.[64,65] Histological features of electrical injury have been described in two South African studies[24,58]

Blumenthal showed that streaming of nuclei was the most common histological feature of all cases sampled (n=11), 9 of which were low voltage [24.] It has not been indicated as to why histology was needed for specific cases and how they contributed to the overall outcome. Notably the vague, and lack of findings associated with low voltage electrocutions, sometime supports the use of histology.[12-20] Von Caues noted streaming to be the most common histological finding in the 17 cases sampled. Other microscopic finding , similar to those of Blumenthal were commented on and present in only 15 of the cases. Both studies concur that such histological features may also be seen in burns. In contrast, Ackan's study on childhood electrocutions, showed that histopathological findings in 34 cases (n=37) were consistent with electrocution, although not described.[63] Behera et al looked at 25 electrocutions with matched controls of histological features and could not differentiate between ante and postmortem electrocution burns. The authors noted that graded features in the dermis including homogenisation of the dermis could be useful to distinguish between ante and post mortem burns, however, concluded that this finding was limited by a small cohort.[65]The use of histology in literature does not appear to be conclusive in electrocutions, and the absence of suggestive findings even in the presence of witnessed electrocutions, is noted.

Some studies have tried to establish the effect of alcohol in electrocutions. Alcohol has been implicated in different types of unnatural or violent death due to its effect on victims or perpetrators,[64] but the effect on electrocution remains circumstantial. Electrocutions are just as likely to occur in the absence of alcohol use ; the interpretation of the mere presence of blood alcohol in such a death, is also unknown. Studies on electrocution have documented from 11,1%, ,20% to 24,6% of cases that were positive for alcohol in blood samples. Studies may or may not test all cases for alcohol, and the reason for exclusion is not indicated in the studies discussed.[48,58-55] In South Africa, Von Caues showed 3 cases out of 27 blood alcohols sampled ranged from

0,01gm/100 to 0,15gm/100ml.[55]The legal limit in South Africa for driving under the influence (0,05gm/100ml),[58,48,66,]but the significance of this threshold has not been correlated with an increased risk to electrocution.

Some Western studies on electrocution showed that fewer cases of positive alcohol occur in a working environment.[48] An Irish study documented a positive blood alcohol in more suicide electrocution cases than accidental, but considered that some samples may have been compromised by decomposition.[1] A South African toxicology study on unnatural deaths which included a single electrocution acknowledged increased alcohol levels with precipitate negative behaviours [66]The study, however cautioned that the various methodologies of sampling and analysis in different mortuaries and laboratories must be acknowledged in the interpretation of results.[66]

Some studies have included other substrates such as urine and muscle to test for alcohol and showed positivity in fewer samples than blood,[48,49] the majority of which showed positivity in a domestic environment.[48.] Overall, Lindstom noted that whilst electrocutions decreased, the cases with positive blood and urine alcohols remained constant and indicated that other factors need to be considered to reduce electrocution.[48] Incidentally, a South African study showed a stark relationship of illicit drugs and non natural deaths in general.[58]This is in concordance with the study in Maryland electrocutions which showed almost twice as many electrocution victims tested positive for cocaine and opioids than alcohol.[55]

Most electrocutions are accidental.[12-20,44,43,44,45,46,53,] Australian studies however, have identified a national concern regarding suicidal electrocutions [46,47] with the Croatian study identifying an increasing trend of suicides against the decline of fatal electrocutions in general.[49] Some studies chose to exclude suicides.[48]Although it is not within the jurisdiction of the South African forensic pathologist to denote the manner of death in autopsy reports, each of the two South African studies documented assumed suicide in two cases[24,58] The difficulty to distinguish electrocution based on manner is well documented in literature.[14]Therefore, despite a lack of mandate to denote manner

of death in South African medicolegal framework, it may be worthy to establish how such conclusions were made for statistical trends and to guide judicial governance.

Given the above, it is acknowledged that electrocutions, although highly preventable, warrant an appreciation of the demographic, social and temporal circumstances in order to implement a strategy. This is a dynamic process that is evolving with urbanisation. Currently, there are no available autopsy-based studies of the demographics of electrocution fatalities in KwaZulu Natal.

Table 1: Highlights of studies discussed in literature review(alphabetical order)

Author	Pl	Y	Study type	Profile	Circumstance	Postmortem findings	Strengths/ Limitation	Trends	Remarks
Ackan[63]	Adana Turkey	1999-2004	Autopsy Retro-spective	All children 37 M: F=5.16 Av age 11.35yrs	91% domestic LV At home=19	Similar injuries to Adults 3cases - no features of electrocution 4 cases no injuries at Postmortem No oral injuries	Large number of histology cases confirmed electrocution. No description of findings	No trend	<6yrs , most victims overall. Female most victims were 0-6years.
Australian Institute of health and welfare [46]	Australia	2014-2016	Coronial (including autopsy reports)	40 fatalities Males (91%) Main age group-45-64yrs	73% domestic. Stratified area of electrocution	No autopsy features	Stratification-Risk areas identified Suicidal electrocutions highlighted .	Decreasing trend 2014 -2016 , Overall decrease over17year period (03/100 000 to 0.1/100 000) between 1999-2016.	**No histology** **No comment on use of alcohol and drugs, especially in relation to suicides**
Bailey[43]	Quebec, Canada	1987-1992	Retro spective Coronial Case study	124 Males:F120:4 Adults Mean -35years Children 9years(7%)	LV-39% (50% due to household voltage)	Postmortem in 112 20 victims-non specific findings 10 victims(8%) no external findings Non specific cardiac signs	Histology (1) Reason not indicated Different pathologists.		**Presumed arrythmia as a cause of death in relation to timing of death.**
Blumenthal[24]	Gauteng, South Africa	2000-2004	Retrospective autopsy based NIMMS and mortuary data	126 All ages Male-26-50years 35 cases(LV) <25years 6 cases(HV) <25years	91 LV 35 HV LV indoors(78,4%) HV (88,57%) outdoors Of the 91 LVcases, (86.81%) not witnessed, HV 29 cases(82.86%) not witnessed,	BAC 4 cases LV(0.03 g, 0.11 g, 0.15 g and 0.29 g per 100 ml) 2 HV (0.02 g and 0.29 g per 100 ml)	Ω LV (%) / HV P: 29,67 / 22,86 G: 26,37 / 5,71 M: 2,2 / 2,86 J: 18,68 / 40 R: 8,79 / 2,86 D: 14,29 / 25,71	No trend	**Data poorly indicates circumstance. Histology done in 9 cases could be compatible with thermal burns.**

Byard[59]	Dual-Adelaide (A) San Diego(SD)	A-1967-2001 SD-1988-2001	Retrospective Autopsy	16 10mo-15yrs Av-8yrs M:F 5:3 3 SD 13- A	# Circumstances	4 victims no injuries, all wet No oral injuries		No trend	**Adelaide11% of all electrocutions for all ages (1967-2001)**
Dokov[51]	Bulgaria	1965-2006	Autopsy based	Accidental (78,06%). male 4th decade of life. <18yrs= 21,65% - 0.12% (±0.02%) of all forensic autopsies.	351 electrocution cases 37,71% of cases solely due to electrocution 63, Domestic (78%) 13,39% in occupational). M:F ratio in domestic circumstances was insignificant (1.17:1.)		Long period of study No elaboration on method Discrepancies in number of cases reviewed Stratified age groups according to United Nations requirements. 63,15% of all electrical injury related fatality due to another cause-no elaboration.	No trend indicated	**Study titled low voltage electrocutions. Vague as to whether all electrocutions discussed were only of low voltage.** **Some deaths appear to be associated with high voltages. Eg electric wire theft.** **No definition of electrocutions included.**
Kutic et al[49]	Zagreb Croatia	1991-2010	Autopsy based, Retro spective.	N=89 M-78(88%) F-11(12%) Av age-40years Minors(<18yrs-14 (16%) 13 M,1 F (mean 11,4 years), 11 minors -electrocution Sole cause of death	Summer Accidental LV-75% HV22% No voltage indicated 1 Domestic-74% No indication of place in 25% of autopsy reports Occupation -low voltage 64%, HV32% blood and urine (range 0,53g/kg;3,91g/kg and 5,81g/kg) from most electrocution victims 0 or < , 0,5g/kg	2 – submersion 1 -head injury Joule burn-79% No detectable skin changes 21% 9 cases showed no marks- all related to damp environments) Entry mark in 43% Entry and exit-20% Overwhelming burns 16% Palm -58% ,overall upper extremity-74%	On suicide victims, entry sites> head and neck, trunk and lower extremities reflecting inventive suicide procedures. Multiple entry wound strongly associated with suicide	Decreasing 3,85 /year 0,36/100000 Incidence decreased 0.39 to 0.14 deaths per 100,000 population Suicidal electrocutions increased number too small to indicate significance	**No histology although recommended** **Stratified place of electrocutions; domestic electrocutions :bathroom (27% -73% woman** **Bathroom-deaths** **The activity amongst childhood electrocutions in this study is noteworthy**
Keyes, Liphoko[57]	Johannesburg, South Africa	2010-2014	Retrospective autopsy	28 Mortality rate - 0,3/100 000/ All Males- 30-39-	Summer: Dec-Feb		Chest was the most common area affected 57,1% of cases R arm 50%	Decreasing	**No victims under 10years**

				0.36 mortality rate					
Lindstrom [48]	Sweden	1975-2000	Retrospective autopsy	285 Male-Av age 38yrs Children 48 -12 <10 years 132 occupational deaths all male (av 42years 0.36% (range 0.15–0.52) of all accidental deaths.	Railways22% Domestic(19%) Rest-substations (11%), farming (9%), and others (40%). Steady positive alcohol level-consider other factors. Acknowledged missing cases.	218 blood alcohol-positive in 20%. 218 Urine alcohol-5 positive in urine but not in alcohol. 135 drug tests, 2 positive.		Steady decrease in electrocutions significant decreases in electrocutions per 5-year intervals.	**Lengthy study may miss occupational statistics related to labour laws. Identified mismatch of cases between two data sources. 'Electrocution'' defined but did not include falls.**∞
Massey et al[55]	Maryland ,USA	2005 -2015	Autopsy Retrrospectiive	N=55 5.5 cases per year Incidence rate 0,092/100 000 M 90,9% Av- 40years 70,1% due to high voltage(N=39)	Work related-63,7% Outdoors-76,4%		Commented that no studies comparing non worker electrocutions to workers in the US. Studies are primarily occupational based.	No comment, Graphical trend of decrease and the plateau with no explanation Occasional spikes Of maximum 8 fatalities each(2006 and 2011)-no explanation for peaks.	**Attributed electrical burns seen due to low resistance as a result of sweating(80% burns)- not in accordance with findings elsewhere.**
Oruc[50]	Malatya , Turkey	2012-2019	Autopsy retro spective	N=49 M Workplace-based electrocutions were reflected in the high number of males (87,8%,n=43); in this study, 31-40 years old were the most affected.	.LV (n= 25 ;51%) HV (n=24;49%) were almost equivalent. 27(55.1%) of all cases were urban based 22(44.9%) in the rural area. HV city centre (62% of cases) mainly workplace accidents(91,7%). LV rural areas(52%), mainly in the workplace (56%).	Electrical entry and/or exit wounds were determined at a significantly higher rate in domestic accident electrocutions than in workplace accidents (p = 0.004).	Incomplete case files were excluded as well as cases where the implication of electricity exposure was dubious.	Trends could be associated with the voltage of electricity Fatal electrocutions increased 2012 to 2016 followed by a decrease. However high voltages accounted for twice as many deaths in 2016 and a spike in 2019	**Exit wound in domestic statistically significant in comparison to workplace exits.(0,017) as well as entry and/exit wounds(p=0,004)**
Pointer and Harrison[44]	Australia	2001-2004	All registered deaths from	162 25-64(64%) 15-24(16%) 0-14(4%) 0-12=n=6			7 new cases from Coronial data		

			electrical injury	65+-(15%)					
Ragui[53]	India	2007-2010	Retrospective Autopsy	25 -24 M No fatalities < 10years 21-30years	Outdoors High voltage All accidental 80% immediate death				
Shaha and Joe[52]	India	2002-2006	Retrospective autopsy	118 electrocutions All 21-30 Males:females: 9.72 2 fatalities<10yrs	104 dead on arrival in hospital Domestic 73 cases Accidental, live wire=n=62 Low voltage n=98		8 no electric mark l Joule burns(93%), 14. with other nonspecific bums, 96 - no other burns. 8 (6.77%) no characteristic electrical bum 5 had other non-specific burns 3 no bums at all.	Summer	**27-epicardial and pleural petechiae.** **21 petechiae of the face, chest or conjunctivae** **9 - petechial haemorrhages of the skin and viscera. Small superficial injuries were rare**
Sheikhazadi[56]	Iran	2002-2006	Autopsy retro spective	N=295 0,6% of all autopsy cases. M:F 17,4:1 Age11mo-73years 11 victims aged(0-10years)	9,6,6% accidental Suicidal3,4% No homicides Domestic (28,8%), ¥	Upper extremity 66,3%, chest 15,4% Electrical mark present in 103 cases (34.9%), Entry +exit 176 (59.7%), No electrical burn marks in 16 cases (5.4%) Died immediately60,7% Dead on arrival31,9%		Trend increasing Av 59 victims /year 0,7/10000 Mainly in summer	**No histology**
Shih et al[42]	World wide review	1946-2015	Global retrospective review	Clinical 7,8% N=71* Adults only	38 single institutions. 3 coroner reviews Autopsies 1165		735 low voltage(63%) 306-high voltage(26,3%) 124(10,6%)no specified voltage 31% lightning	Not indicated	**Single institutions may skew results**
Strivastra et al[54]	Jaipur , India	2016-2017	Retrospective-Tertiary hospital based	All burn admissions(1572) Electrocutions--8,5% of all fatalities			Overrepresentation of high voltage injuries. Low voltage injuries may be underrepresented.		**Low threshold for hospital admission of high voltage injuries'**
von Caues[58]	Stellen bosch,	2008-2012	Retrospective autopsy	39 All ages	Mostly during the day-06h00-18h00.	27 tested 3 positive	Highlighted potential concern	Summer (36% of cases)	**Small cohort**

	South Africa			21-35.n=15 10 victims (25.6%) were aged<13yeras 6 less than 5yeras(15,4% of study pop)	8 deaths(all HV) related to cable theft and attempted theft. 4 of these in railway stations 5 due to illegal wiring ,4 in Khayelitsha 10 could not be confirmed due to illegal wiring-60% of these in Khayelitsha. 4 near railways	0,01gm/100ml-0,15gm/100ml. Macro: injuries: Crateriform 16 (47.1) Blistering 15 (44.1) Parchment-like lesion 11 (32.4) Crocodile skin 2 (5.9) Charring	in younger victims. Histology Blistering-10 Streaming-10 Necrosis 6 Palisading 4 Elongation 3 Hyper eosinophilia Pyknosis[58]	No reason on this particularity in Western Cape	**Incidence is questionable. Histology in 17 cases majority s (15 show features of thermal and electrical burns. DOA erroneously included under hospital deaths.**
Wick et al[47]	Adelaide, Australia	1973-2002	Autopsy retrospective	N= 96(95 electric, 1 lightning) Adult fatalities (>16yrs Males-91% Mean age41,6years Females-mean49,6years	LV-83% Accidental-66% Suicide-29% Homicide-2% victims, both females	80% (n=83,3%)characteristic electrical burns 68 - low voltage. 11 of these had additional non specific burns. 16- absence of typical burn 9 other nonspecific burns 7 no burns at all Only 1 case noted in bathtub. Petecchiae-11 cases No cases with fractures due to direct current. 1 case of blunt force injury due to fall.		Trend- increased accidental deaths till1990 then decreased. Suicides not documented in first 10 years. Summer predominance in accidental deaths Suicides all year round	**Homicides and suicides may be difficult to differentiate. Varied injury distribution compared to other cases suggested due to different autopsy practice**

*exposure to electrical transmission lines (9.1%), exposure to other specified electrical current (32,7%), unspecified electrical current (9.1%), intentional self-harm by other means including electricity (30,9%) and other specified events of undetermined intent (3,6%).[5]

Ω. Medicolegal mortuaries % LV and HV cases P-Pretoria ;M Medunsa, G Germiston; J-Johannesburg, R-Roodepoort, D-Diepkloof, ,Bronkhorstspruit not in table (not indicated -0 electrocutions)

#playing with or near faulty electrical equipment at home or at school (n = 8), electrical equipment while in the bath (n = 2),damaged outdoor electrical equipment (n = 1), overhead wires(n = 1), and a high-voltage electricity substation (n = 1)

∞**'Electrocution'' as the cause of death was defined as any combination of electric shock, burn injuries caused by arc light, and injuries by caused by falls from a height due to electric shock.**

¥64 (21.7%) inside buildings during the electrical work, 52 (17.6%) in the street, others in various places of services .touching electrical cables (95 cases, 32.2%), by touching electrical wires (67 cases, 22.2%), dynamo at work place (39 cases, 13.2%)amongst others

CHAPTER 3-Research design and methodology

3.1 Context

This study is a retrospective analysis of electrocution fatalities seen at three medico-legal mortuaries in the eThekwini metro from 2006 to 2016. Data regarding electrocution fatalities was obtained from autopsy registers, postmortem reports and in two cases, police dockets consisting of all information pertaining to the investigation of an alleged crime to date. In those two cases, circumstances regarding the cases presented as community assaults and were subsequently concluded as electrocution by attending pathologists. With the exception of an electronic database in Gale Street Mortuary, all other data was paper based. Findings were collated on an Excel spreadsheet and included demographics related to age, sex, place of occurrence, time of occurrence, anatomical distribution of injuries, and analyses done, including histology and toxicology.

Ethics for this study was obtained from the University of Cape Town Human Research and Ethics Committee (825/2020). Permission to conduct this study was sought from the Provincial Department of Health, KwaZulu Natal (NHRP KZ_2016 RP56_162). Waiver of informed consent was granted as the study represented a retrospective chart review of forensic mortuary data. Anonymity and strict confidentiality were exercised as is mandatory for all medico-legal cases.

In South Africa, death by electrocution is regarded as an unnatural death that necessitates the performance of a forensic post mortem as per section 3 (2) of the Inquests Act.[67] Electrocution deaths fulfil one of the four criteria that dictate the legal obligation to perform an autopsy: applying an external force on the body through physical, chemical or mechanical factors. Medico-legal mortuaries function under the statute of the National Health Act, Inquest Act [67]and other relevant legislation. At these facilities, forensic medical practitioners conduct autopsies on all unnatural deaths, including consultants, medical officers, and registrars in an academic training programme.

The Forensic Pathology Services in eThekwini, KwaZulu Natal, under the auspices of the Department of Health, sees an average of 2324 unnatural deaths per year. It is recommended that forensic medical practitioners visit crime scenes, although it is often not possible due to the extensive caseload. History of incidents is documented on the police referral form, together with hospital notes if available, and the practitioner may further investigate as she or he sees fit. External examination of the body is followed by autopsy, emphasising macro pathology. The practitioner may undertake additional investigations as required.

3.2 Sites

A retrospective descriptive register-based study reviewed all possible fatal electrocutions autopsied at three medico-legal mortuaries in the eThekwini metropolitan municipality of KwaZulu Natal (the second-most populous province in South Africa).The province is located in South East South Africa, bordering the Indian Ocean and covers 94361km^2, making it the third smallest province, out of nine, in South Africa. Kwa Zulu Natal is one of nine provinces in South Africa. eThekwini is the smallest district in KwaZulu Natal with the largest population per square kilometre(1502,34 people per km^2).[68] Zululand, the district that covers the largest land area, in contrast has a population density of 54,3 people per km^2. The eleven municipalities in KZN constitute the metro (eThekwini and ten district municipalities). Gale Street, Phoenix and Pinetown mortuaries service the municipality, which has an area of approximately 2297km.[68] Data over an 11year period from 1st January 2006 to 31st December 2016 was analysed.

The population for the eThekwini municipality according to the reported 2011 census is 3 442 361.[69] This rose to 3 987 648 in 2016.[70] KwaZulu-Natal had the second largest population in South Africa after Gauteng with an annual population growth rate of 1,7% between 2011 and 2016. This is the same growth rate as Western Cape, even though Western Cape has only the fourth largest population in the country. The population in eThekwini is predominantly young, with 66% below the age of 35years (0-14years 25%, and 15-34years, 41% respectively). There is a slight predominance of females than males in the eThekwini demographic profile (51% versus 49%). The economically active age group is primarily in the 15-59 years range and constitutes

approximately 67% of the population.[69,70]The predominant age group has shifted from the 15-29 year olds in 2011 to the under 19 years in 2016. with the number of children increasing by 2,9 percentage points. eThekwini has the highest number of children 0-4years amongst all 11 municipalities. Ten percent of households in KwaZulu Natal have no access to electricity (2016) with 36,9% having access to inhouse electricity meters in eThekwini.[68,69,70]

Gale street mortuary services primarily serve the city centre and south regions; Phoenix mortuary provides services for the northern and north-central regions, and Pinetown mortuary services the inner west and the outer west regions, with a combined annual intake of medico-legal post-mortem referrals of over 6000 cases. Cases admitted at these facilities also include cases referred from hospitals, some of which are located outside the service perimeter.

3.3 Sampling strategy

Data of deaths categorised as “due to electrocution”, “consistent with electrocution or a history thereof”, or “due to electrical injuries” were sourced from the computerised databases at two facilities and a manual database at Phoenix Medico-legal mortuary, as well as daily allocation lists and death register entries from the three mortuaries. The principal investigator collated a total of 512 cases fulfilling the criteria of an electrocution fatality.

Data sources included all documentation related to forensic post mortem records, including daily case allocation sheets, post mortem reports, ancillary toxicology and histology reports, police and hospital referral forms and relevant statements and the electronic and manual death registers. The SAPS 180 form is a nationally recognised template filled in by South African police officers at the scene and provides demographics including age, sex, circumstances of death, time of death and a brief summary of the history surrounding the death. Sudden unexpected deaths, burns and "other" causes of death were also reviewed to exclude any relation to an electrical event. Electrocutions following lightning were excluded, as well as missing, incomplete reports. The rationale for excluding lightning deaths was in view of the following:

1. Few studies actually differentiated between lightning and non-lightning.

2. Overall there are few autopsy based studies regarding all electrocutions.

Therefore, in order to reflect the magnitude of electrocutions, it was important firstly to indicate the scope of the problem, and then to delineate non lightning electrocutions, which has preventative potential within the capacity of municipalities and individuals.

Data were collected and entered into Microsoft Excel Spreadsheets. Information from data sources was used to develop composites regarding circumstances of the incident (viz. activity at the time of electrocution, source of electrocution if known) and temporal profiles, including victim's sex and age, alcohol concentration, histology taken, presence of electrical "Joule" burns or injuries on the body and non-electrical injuries. Data related to the spatial circumstances were collected and included area or place of death, nature of electrocution , date and time if indicated, and season. This data was tabulated for each of the variables and frequencies calculated.

3.4 Location of cases

Some SAP 180 forms did not indicate where the death occurred. For the basis of this study, police case numbers were used as locations of the cases. Forensic Pathology services subsequently took the cases to the mortuary that services the districts as per municipal boundaries.

For the purposes of this study, as discussed above, boundaries are dictated by areas served by forensic pathology services and have been designated into six regions for the period of study. Electrocution fatalities in these regions are documented according to the suburb from which they are collected by the pathology services.

3.5 Inclusion/Exclusion criteria

1. All deaths due to electrocution or electricity-related injuries as documented in the cause of death in the B1-1663 form.

4. Lightning deaths were excluded.

3.6 Statistical analysis

All data were analysed using the statistical package STATA 13 (StataCorp, TX, USA). Frequency distributions were developed for all categorical data. Differences between proportions within a variable were analysed for significance using the Pearson's Goodness of Fit test. Proportions between multiple groups were analysed using Pearson's Chi-squared test.

Numerical data (age) was analysed with the Shapiro Wilk test to determine if the distribution was normal. No data showed normal distribution; therefore, differences between groups were analysed using the Wilcoxon sum rank test for two-group comparison and the Kruskal Wallis test for multiple group comparison.

The level of significance was set at $\alpha = 0.05$ for all statistical tests.

Population data were obtained from data extracted from the 2011 national census (https://census2011.adrianfrith.com/place/599)[70]

Heat maps displaying the distribution of cases across the eThekwini municipality were generated using Tableau software. The shapefiles for the suburbs used in the map were obtained from the eThekwini Municipality GIS website (http://gis.durban.gov.za/datadownloads/showdocs.asp).

Blood alcohol is routinely taken for all unnatural deaths in medicolegal mortuaries in eThekwini. Peripheral femoral vein samples are taken, decanted into sterile glass vials with preservative and anticoagulant and sealed in alcohol kits as part of a chain of custody. All samples were submitted to the Forensic Chemistry Laboratory in Durban. Analysis was conducted by registered forensic scientists. Reports generated provide blood alcohol concentrations, including methodology of analysis.

CHAPTER 4

Results

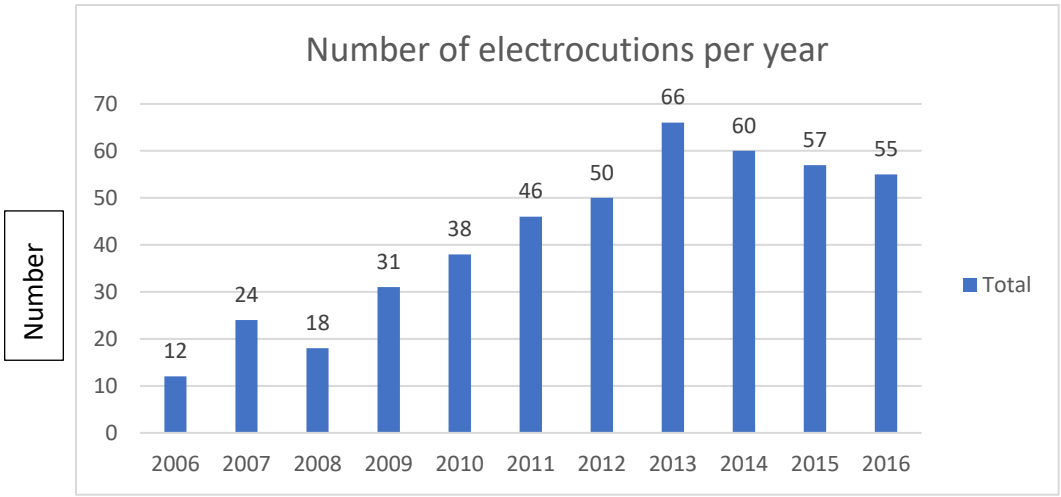
Demographics

4.1 Prevalence of fatal electrical injuries

A total of **512** autopsies on cases of fatal electrical injuries were conducted between 1st January 2006 and 31st December 2016. This accounted for approximately 1 % of total mortuary admissions over this period.[Calculation is based on available admission data at mortuaries over the 11 year period.]

The reported population for the eThekwini municipality from the 2011 census is 3 442 361. This resulted in a prevalence of 1.35 fatal electrocutions per 100 000 population per year. The number of electrocutions per year ranged from 12 to 66 (mean ± sd: 41.55 ± 17.34) (Figure 1). A significant difference in the number of cases per year was seen ($p<0.001$). The general trend was a steady increase in electrocutions annually from 2006 to 2013(peak) and then a gradual decrease until 2016. The majority of cases (225; 43.95%) originated from the Gale Street Mortuary (GSM). This was followed by Phoenix (PHX) and Pinetown with 201 (39.26%) and 86 (16.8%), respectively. A significant association exists between the number of cases each year and the mortuary ($p = 0.001$). (Table 2)

Fig 1: Number of electrocutions per year (n=512)



Mortuary	N (electrocutions)	Mean electrocutions/year	sd	Mean admissions/ year [$]	Prevalence of electrocution (% admissions)
GSM	225	20.45	8.9	2051	0.997
PHX	201	18	9.3	1463	1.25
Pinetown	86	7.82	6.6	1163	0.672

Table 2: Fatal electrocutions investigated at each mortuary (n=512)

[$] Data calculated from admission data for the period 2009 – 2015. Other years were missing, and 2016 data was too sporadic to use.

The distribution of cases of fatal electrocution at each mortuary demonstrates that the Phoenix mortuary handles a greater proportion of electrocution cases to total admissions each year. (Fig 2)

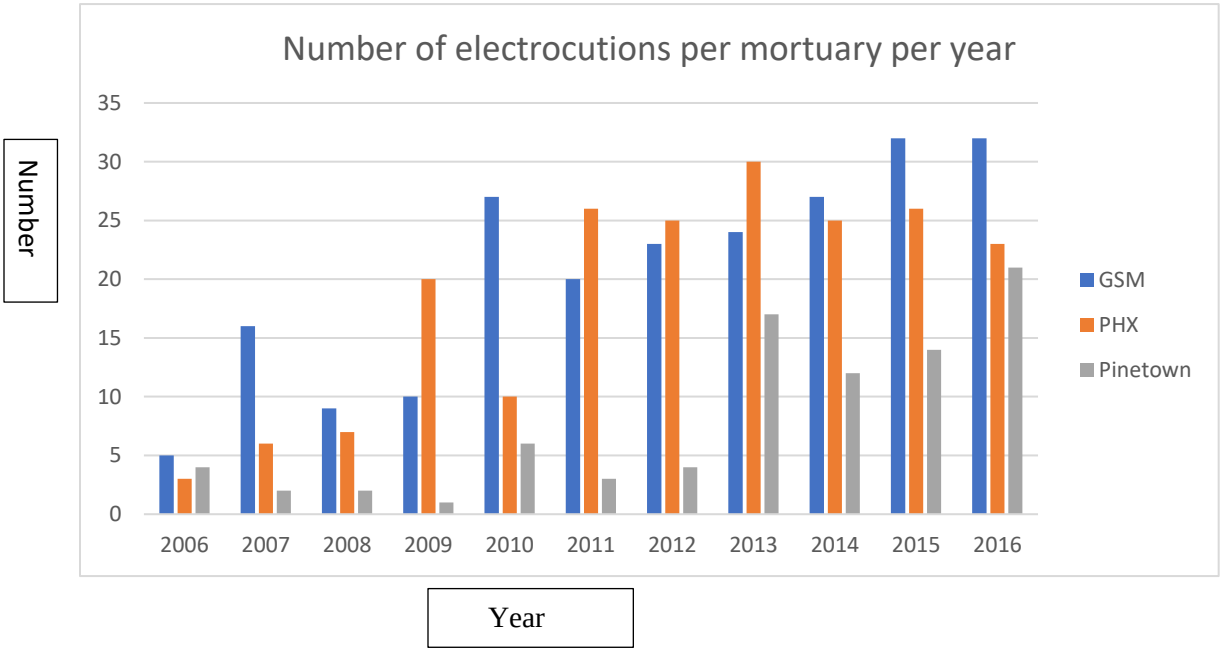


Fig 2: Number of electrocutions per mortuary per year(n=512)

4.2. Age

The ages for 493 of the deceased were available out of 512 cases identified.

Descriptive statistics for the age of victims based on sex, mortuary and year can be seen in Table 3. Overall, the median age of victims was 24 years with a range of 0.75-78 years. No significant differences were noted in the median age of electrocution cases between years (p=0.5447) or between mortuaries (p=0.2022). However, the median age of male victims was significantly greater than female victims (p=0.0017).

Table 3: Descriptive statistics of known age by sex, mortuary and year (n=512)

Characteristic	**N**	**Age in years Mean (sd)**	**Age in years Med**	**Age in years Range**
Overall	496	22.45 (16.09)	24	0.75 - 78
Sex				
Male	390	23.40 (15.25)	25	0.75 – 76
Female	103	18.96 (18.62)	11	0.91 – 78
Mortuary				
GSM	224	21.5 (14.66)	23	0.75 - 74
PHX	188	24.27 (17.4)	25	0.75 - 76
Pinetown	81	20.97 (16.55)	23	0.75 - 78
Year				
2006	11	25.16 (17.40)	26	0.75 - 55
2007	24	21.82 (19.22)	23	0.83 - 70
2008	18	19.50 (15.16)	20.5	1 - 50
2009	31	18.25 (15.42)	15	0.75 - 60
2010	42	20.55 (16.36)	20	1 - 78
2011	47	25.70 (16.86)	25	1 - 72
2012	49	23.10 (15.74)	23	1 - 74
2013	66	23.89 (16.09)	24	0.75 - 76
2014	60	19.73 (15.30)	21.5	0.91 - 70

2015	69	23.83 (15.93)	25	0.91 - 57
2016	76	23.05 (15.83)	26	0.75 - 60

Age categories

Overall, a significant difference exists between the number of electrocuted people in each age category ($p<0.001$). The majority (28.71%) is less than 10 years old; this is closely followed by 20 – 29yr olds (27.15%).

A closer investigation of the 0 – 9-year-old group indicated this group is primarily made up of children aged 2yrs (20.41%) and 3yrs (17.01%).

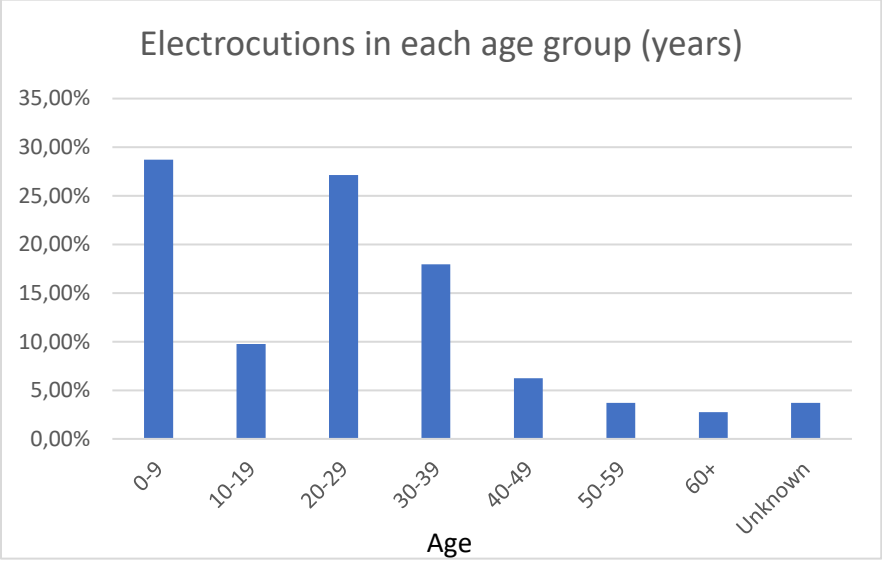


Figure 3: Distribution of electrocutions(%) in each age group in years (n=512)

The under two years were isolated in order to demonstrate active access to electrical connections. This requires an infant to be independently mobile. According to a WHO multicentre study, reference windows for sitting alone unsupported is 4 months to 9 months up to walking alone (reference range 7,5 to 17,5 months.)[71]

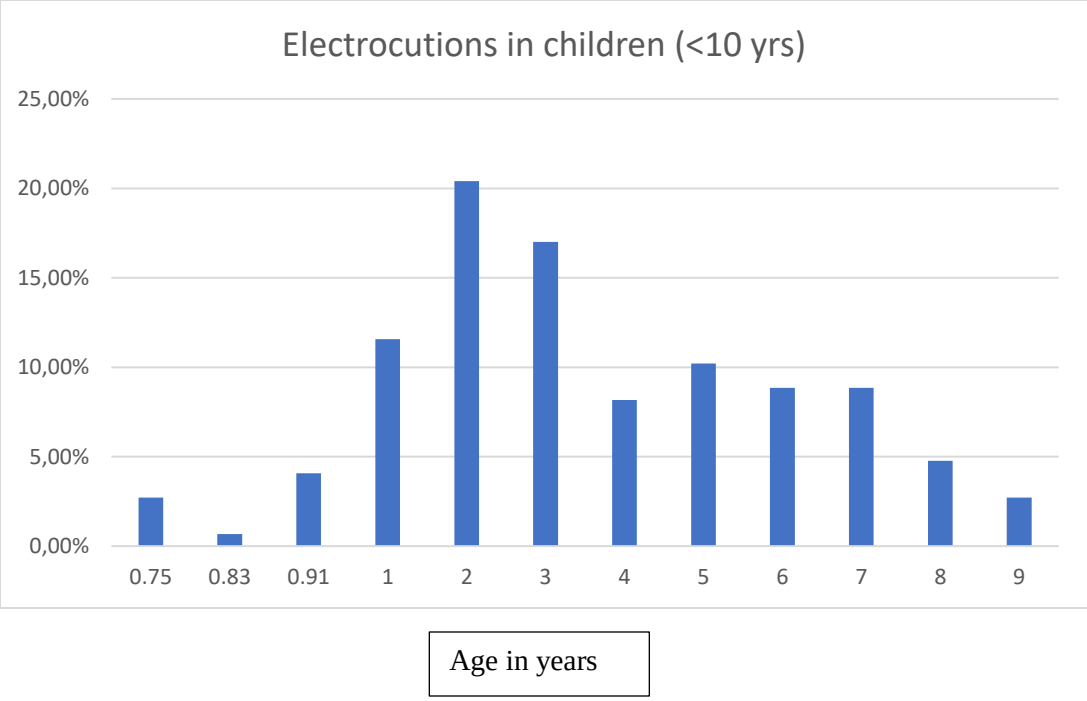


Figure 4: Distribution of electrocutions(%) in children (<10years); stratified for under 2 years. (n=512)

4.3 Sex

The sex of the deceased was known/ recorded in 509 cases.

Overall, more males (79.37%) are electrocuted than females ($p<0.001$). No significant difference exists between the distribution of sex at the different mortuaries ($p=0.343$).

In the general population, the normal proportions in each sex for the eThekwini municipality are male (48.87%) and female (51.13%).[67,68,69] Therefore, in the cases of electrocution, males are overrepresented ($p<0.001$), and females are underrepresented ($p<0.001$).

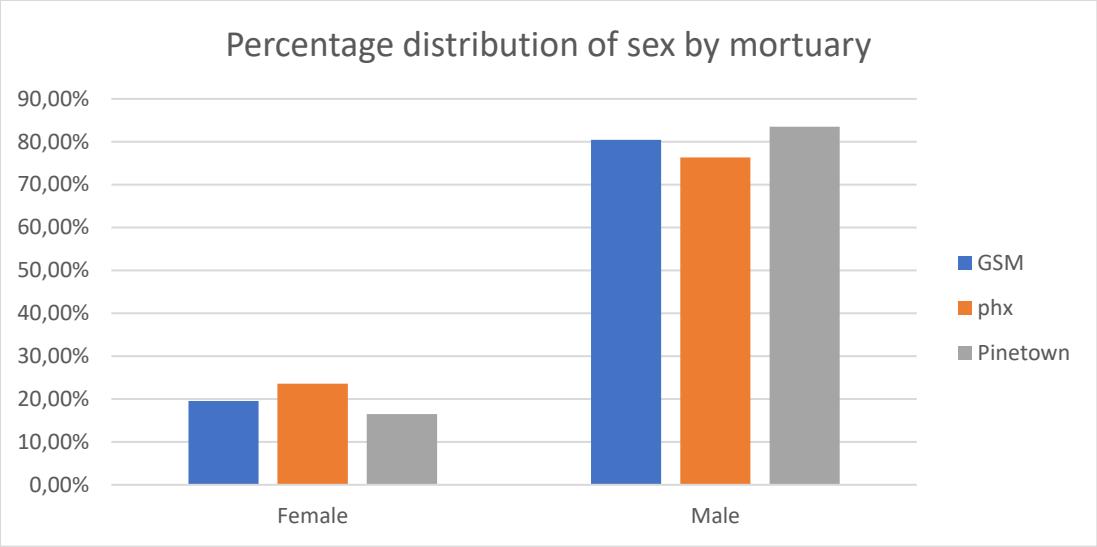


Fig 5: Electrocutions(%) distribution of sex by mortuary(n=512)

Stratifying by sex, there is a significant association with age ($p<0.0001$). Most females electrocuted are less than 10 years old (43.81%), while for males, the majority of victims are between 20 and 29yrs old (30.69%) (Fig 6).

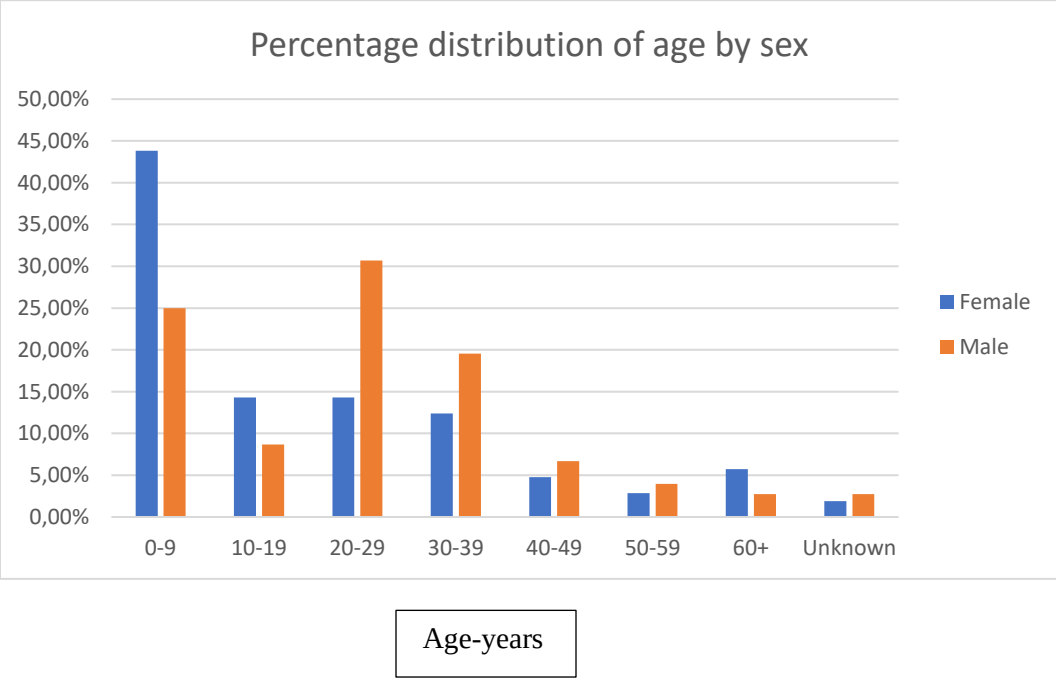


Figure 6: Distribution of electrocutions(%) of age (years) by sex (n=512)

Demographics: Geographic distribution and temporal profile

4.4 Place

The majority of cases occurred in the suburb of Tongaat (61; 11.9%), followed by Sydenham (54; 10.6%), Cato Manor (38; 7.4%), Greenwood park (31; 6.1%), Umlazi (30; 5.9%) and Kwamashu (25; 4.9%).

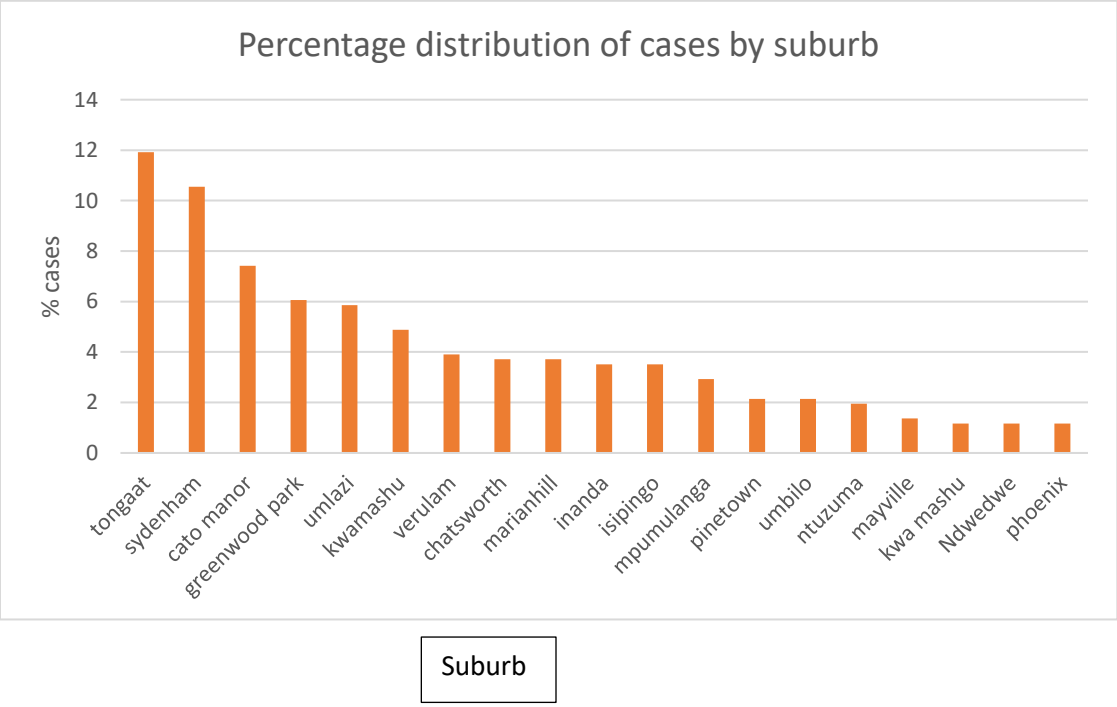
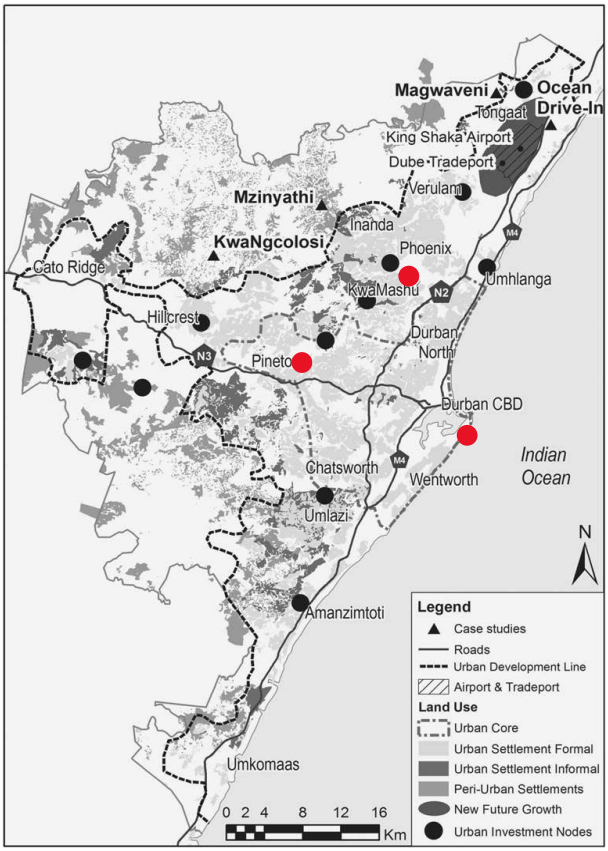


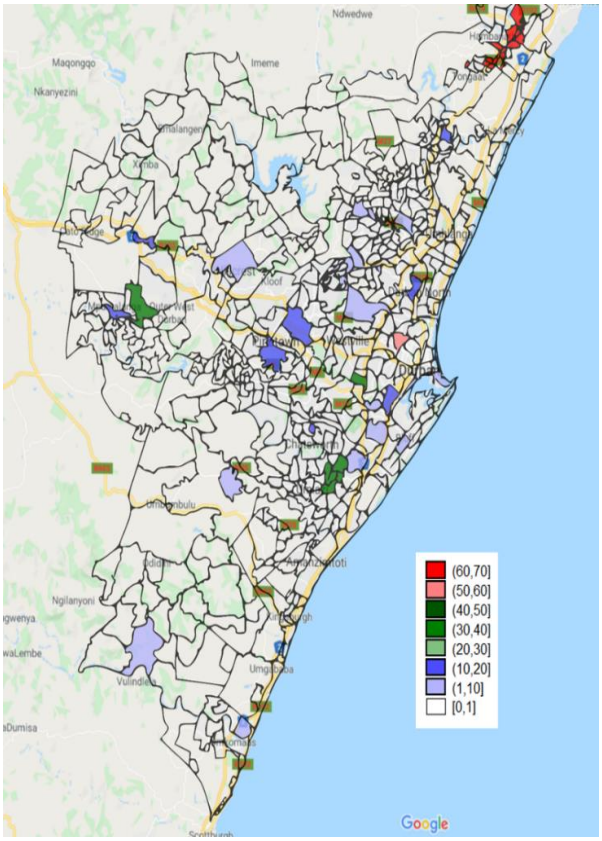
Fig 7: Distribution of electrocutions (%) by suburb(n=512).

Fig 8A; Urban-rural topography of eThekwini in relation to the mortuary service area *

*Map adapted from Sutherland C ,Scott D, Hordijk M. Urban Water Governance for More Inclusive Development: A Reflection on the 'Waterscapes' of Durban, South Africa. European Journal of Development Research. 2015. 27. 488-504. 10.1057/ejdr.2015.49

Fig 8B: Distribution of fatal electrocutions per district in eThekwini (2006-2016)





4.5 Month and season of the year

The mean number of electrocutions per month over the eleven years was 3.81. Most electrocutions occurred during December, whilst the lowest number occurred during June. (Fig 9). In eThekwini, warm temperate conditions are usually experienced between September and March, with the summer vacation falling between December and early January. Winter, which is usually mild and dry, is usually experienced in midyear with 21st June coinciding with the Winter solstice.[141]

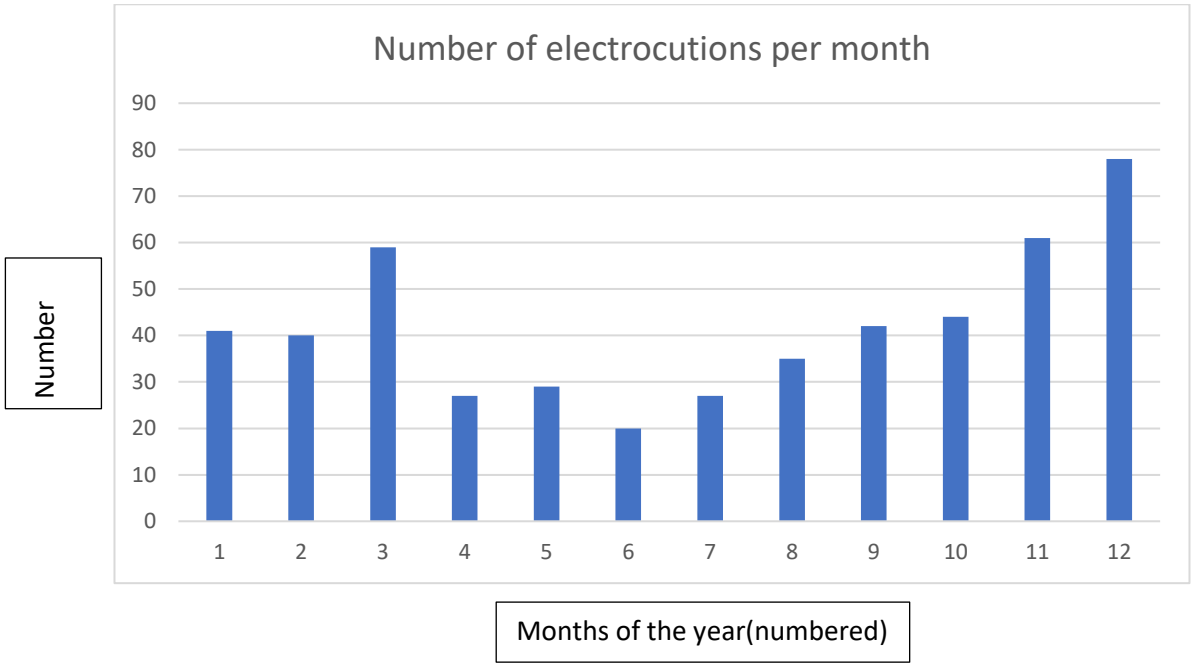


Fig 9: Number of electrocutions per month(n=512)

Most cases occurred in Summer (31.61%), with the least cases occurring in winter (16.3%).

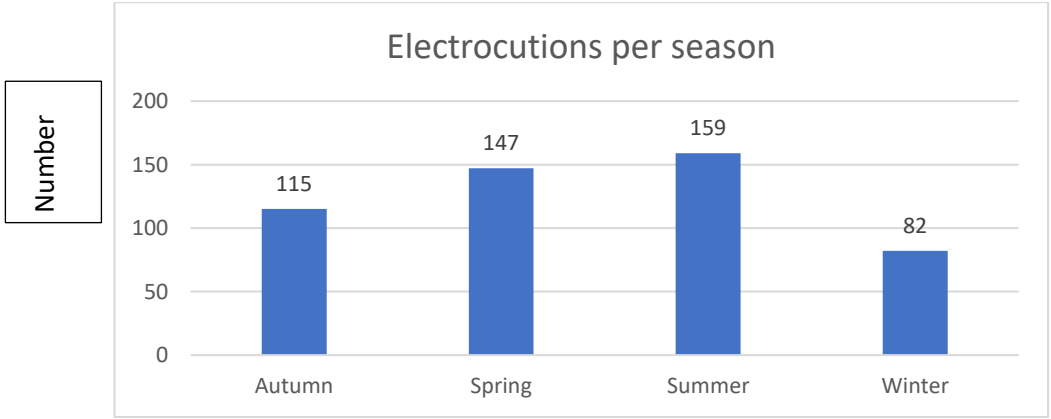


Fig 10: Number of electrocutions per season(n=512)

4.6 Day of the week

Most electrocutions appear to occur on Saturdays (19.8%) and Sundays (19.1%). The least number of electrocutions occurred on Friday(8,5%), with insignificant differences between numbers seen from Monday to Thursday.

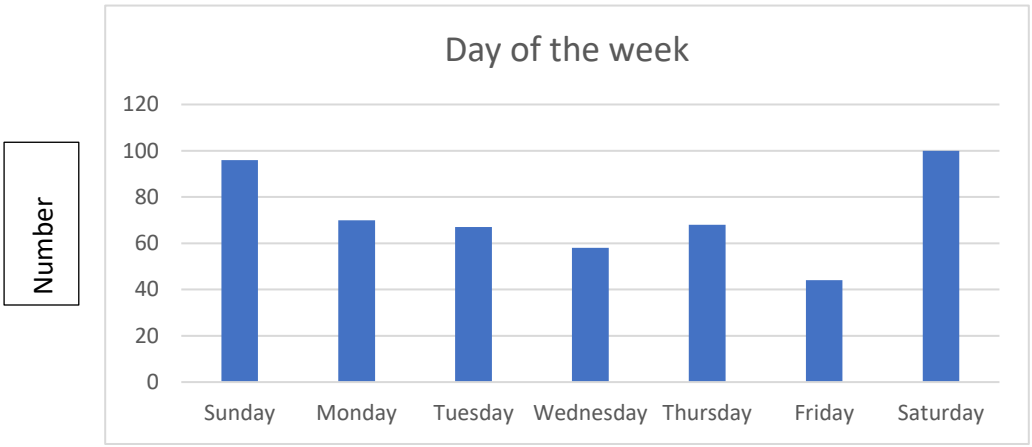


Fig 11: Total number of electrocutions per day of the week from 2006 to 2016 (n=512)

4.7 Time of day

The time of the incident was known in 431 cases. The majority (42%) of cases occur in the afternoon (between 12:00 and 17:59). Very few cases occur in the early morning (00:00 – 05:59) (8.35%). No significant difference was seen in the time of the incident at each mortuary (p=0.351).

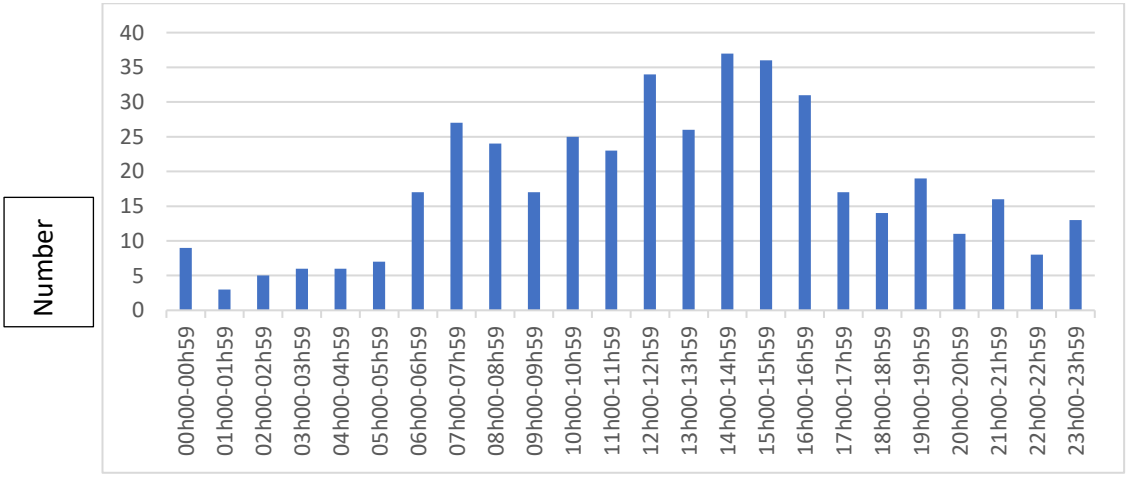


Fig 12.1: Total number of electrocutions over 24 hours, 2006-2016(n=512)

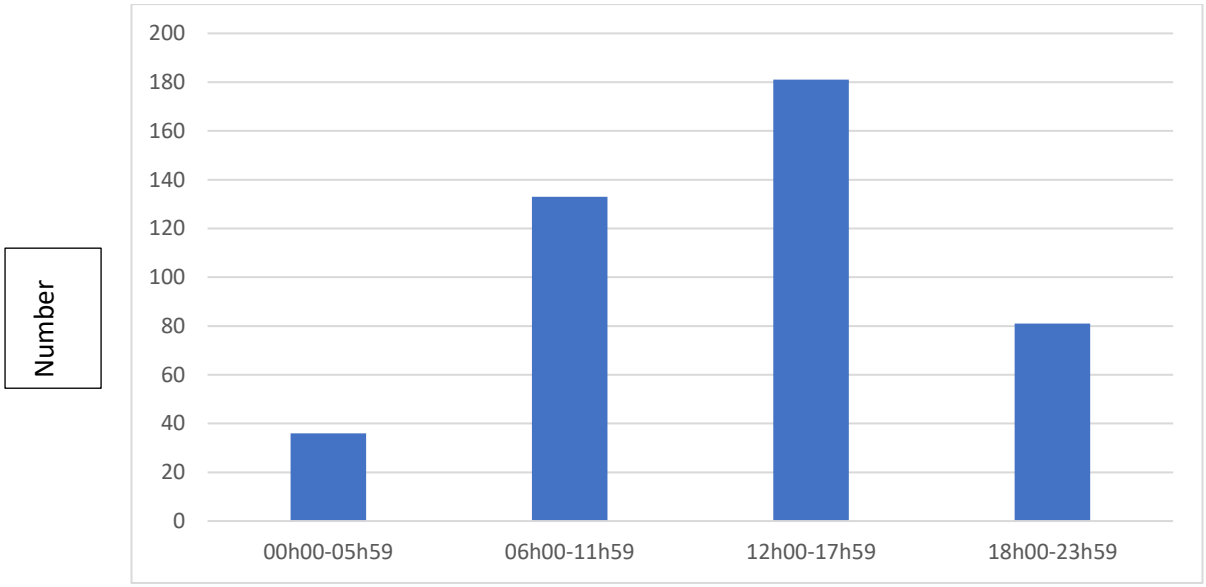


Fig 12.2 Total number of electrocutions per 6 hourly periods (n=512)

No significant difference was noted between the time of incident between females and males (p=0.744).

A significant association was, however, noted with age (category) and time of the incident (p<0.0001). For most age groups, the predominant time of the incident was between 12:00 and 17:59, except for 20 – 39yr olds where the predominant time was between 06:00 and 11:59.

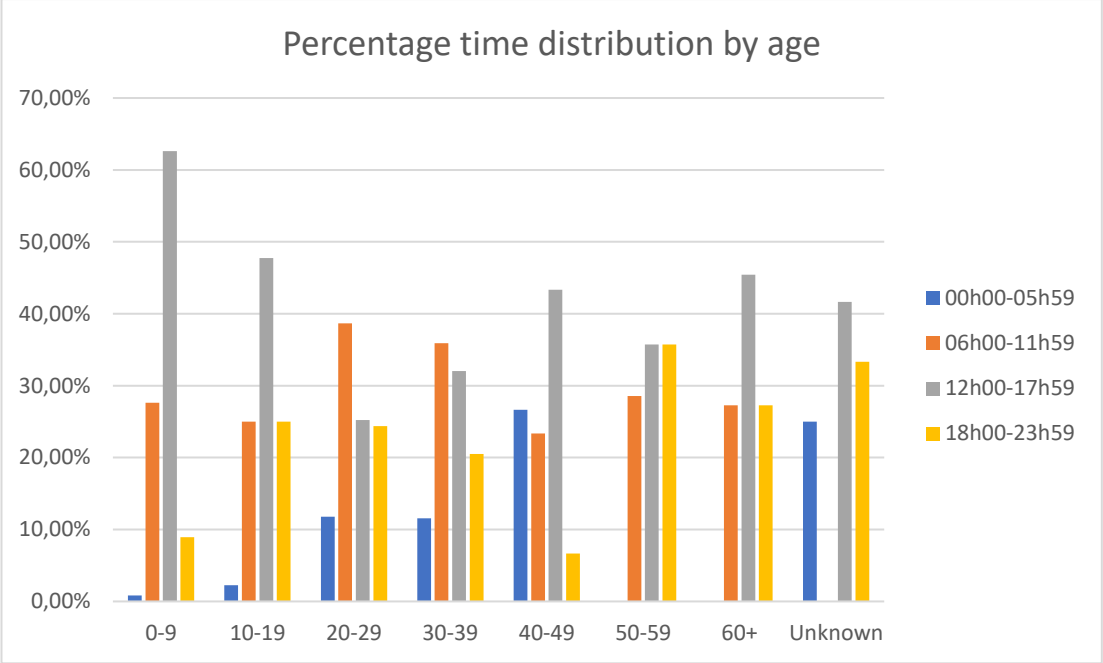


Fig 13: Time distribution of electrocutions (%) by age (n=512)

4.8 Post mortem features of electrocutions

4.8.1 Source of electrocution

The source of electrocution was indicated in 128 cases. (n=512)

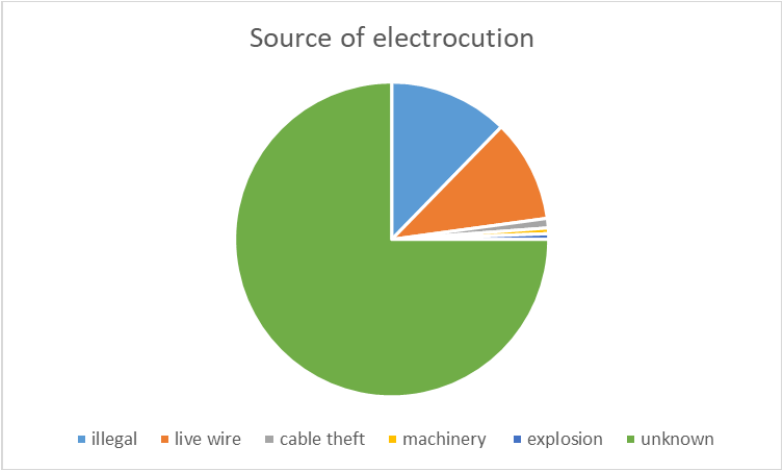


Fig 14: Source of electrocution(%)[n=512]

Illegal connections were the most common documented source of electrocution (n=63), followed by live wires (n=54), cables theft (n=5), machinery(3), and explosion

(n=3). Of the illegal connections, 21 cases occurred in children, 12 males under 10, 7 females under 10, and 2 males in the 10 to 18years. The youngest victim was less than 1 year.(n=2)

4.8.2Anatomical location of electrical injuries

The anatomical assessment of electrical injuries was based on a definition advocated by Blumenthal, as described previously (pg. 28).[24] The majority of cases showed injuries to the hands (48.63%), arms (15.62%), legs (10.94%), chest (10.15%), and feet (8.98%). No significant difference was noted in the proportion of injuries to the left and right sides of the body.

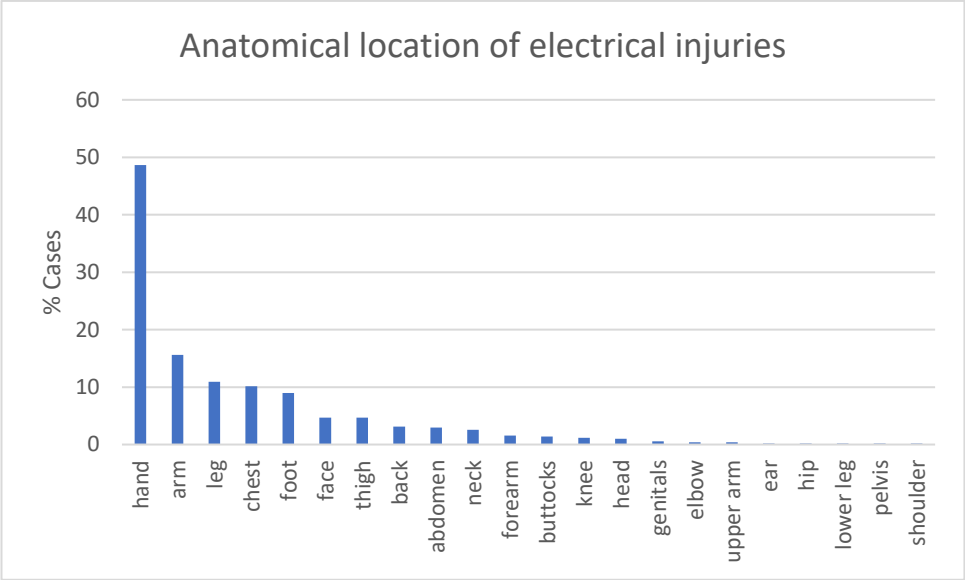


Fig 15: Distribution of injuries per anatomical site in electrocuted victims(%).[n=512]

Joule burns were detected in **63,5%** of cases. The right and left hands were equally affected (24,41;24,21%), followed by the chest (10,14%), by the right and left arms (8,59% and 7,03%), right and left lower limbs (5,66 and 5,27%) feet (4,29;4,68%) and right and left thigh (2,34% each). The left foot was affected more than the right.

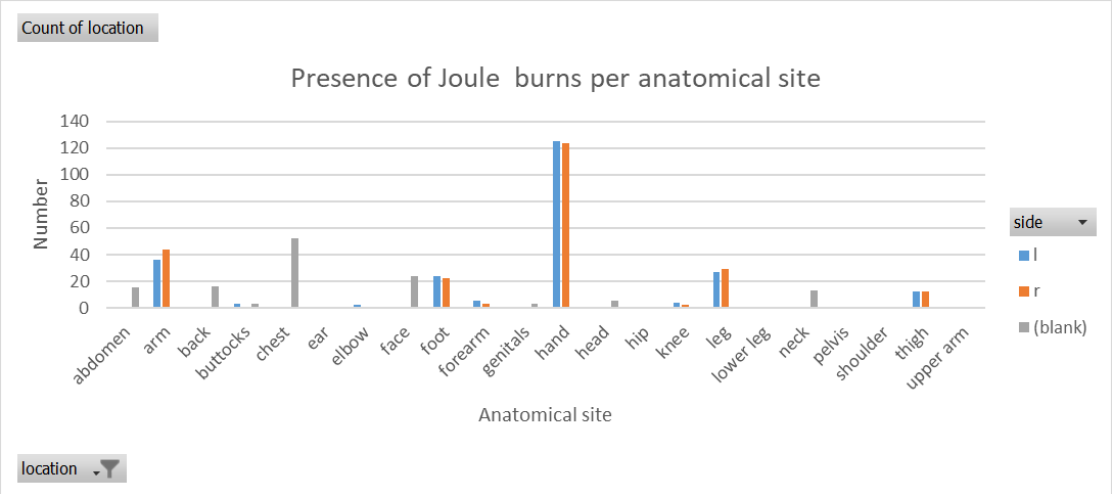


Figure 16: Presence of Joule burns per anatomical area affected (numbers of burns per site)[n=512]

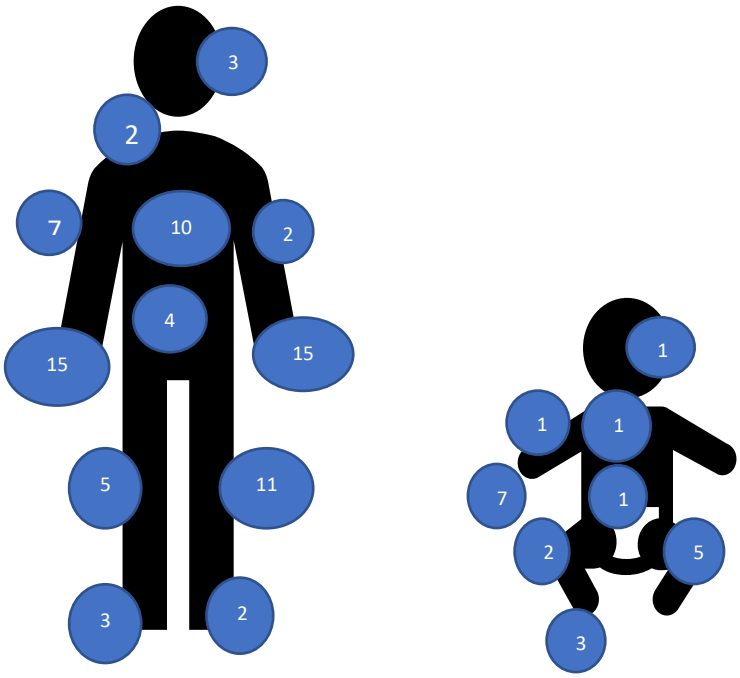


Figure 17: Frequency of injuries related to illegal connections

Frequency	R hand	L hand	R arm	L arm	LL limb	RL limb	Chest	Abdomen	Head	Neck	R foot	L foot
Adult	15	15	7	2	11	5	10	4	3	2	3	2
Child	7	2	2	0	2	5	1	0	2	0	2	0

Table 4: Frequency of injuries relating anatomical area to illegal connections.(n=512)

4.8.3 Non electrical injury related features

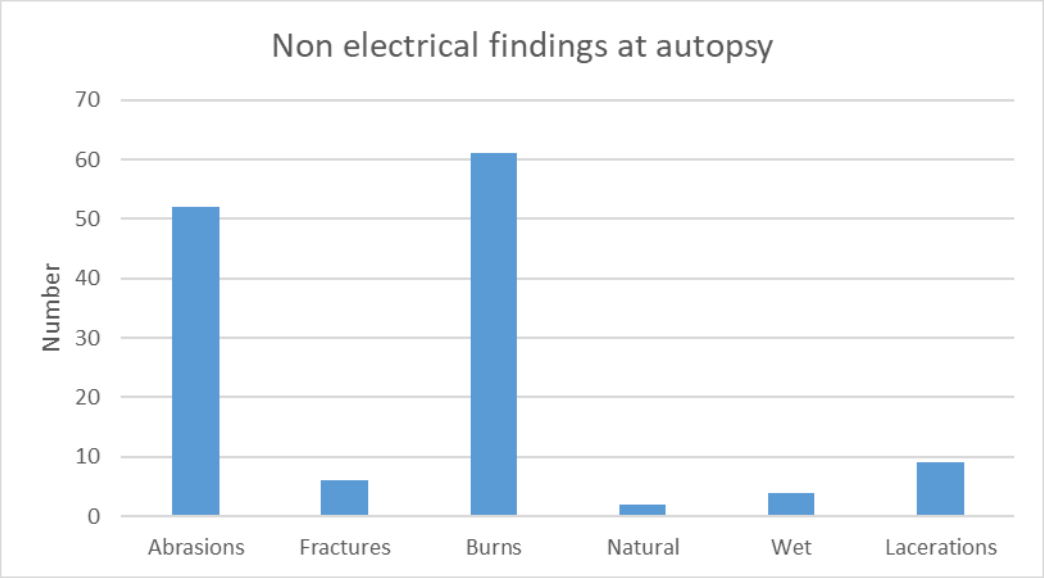


Fig18: Frequency of non-electrical related findings at postmortem [n=512]

Thermal burns were the most common non electrical injury, with 3 cases showing complications viz sepsis, or pneumonia following hospital admission.

4.8.4 Anatomical distribution of injuries in children less than 5years old

A total of 110 children aged 0-5yrs died of electrocution. In 71 cases, the external injury was visible and recorded. Forty-two cases had an injury to a single anatomical region, 18 cases had 2 regions injured and 11 had 3 regions injured.

The majority of children less than five years saw injuries to the extremities, most notably the hands. The distribution of injuries was as follows: hands (47.27%), arms (15.45%), legs (13.64%), feet (10.91%); abdomen (3.64%), face (3.64%), chest (2.73%), back (1.82%) and head (0.91%). The distribution of injuries is not significantly different to that seen in other age groups (p=0.569).

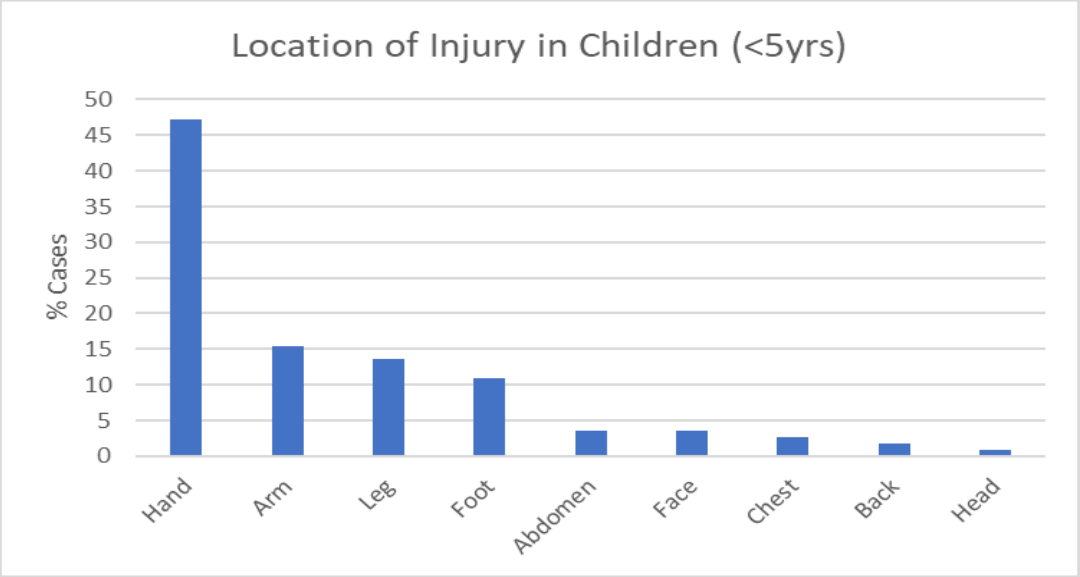


Fig 19: Distribution of injuries per anatomical site in < 5years

4.8.5 Histology

Histology was taken in 85 cases (16,6%).Of these, 6 cases of electrocution were reported on, and 3 cases were confirmed electrocutions. Of the three remaining cases, 2 were concluded as unremarkable and 1 reported on noted shrunken nerves and Purkinje fibre disintegration. There were 48 cases of histology which were bloc and file, with no reports generated.(A process where tissue samples are taken and reported on should the need arise.)

4.8.6 Blood alcohol concentration

Blood was taken for the analysis of alcohol in 244 cases (47.66%). Results were available for 142 cases (58.2%). Most cases had no alcohol in their system (61.27%).

Where alcohol was detected, the mean blood alcohol concentration (BAC) was 0.16 gm/100ml (±0.1). A significant difference was seen in the median BAC between males and females (p=0.0284). No significant difference was noted in the median BAC between the different age groups (p=0.3062).

Table 5: Descriptive statistics of alcohol concentrations(gm/100ml) per sex

Sex	N	Mean	SD	Med	Min	Max
Female	6	0.07	0.06	0.065	0.01	0.18
Male	49	0.16	0.1	0.15	0.01	0.55

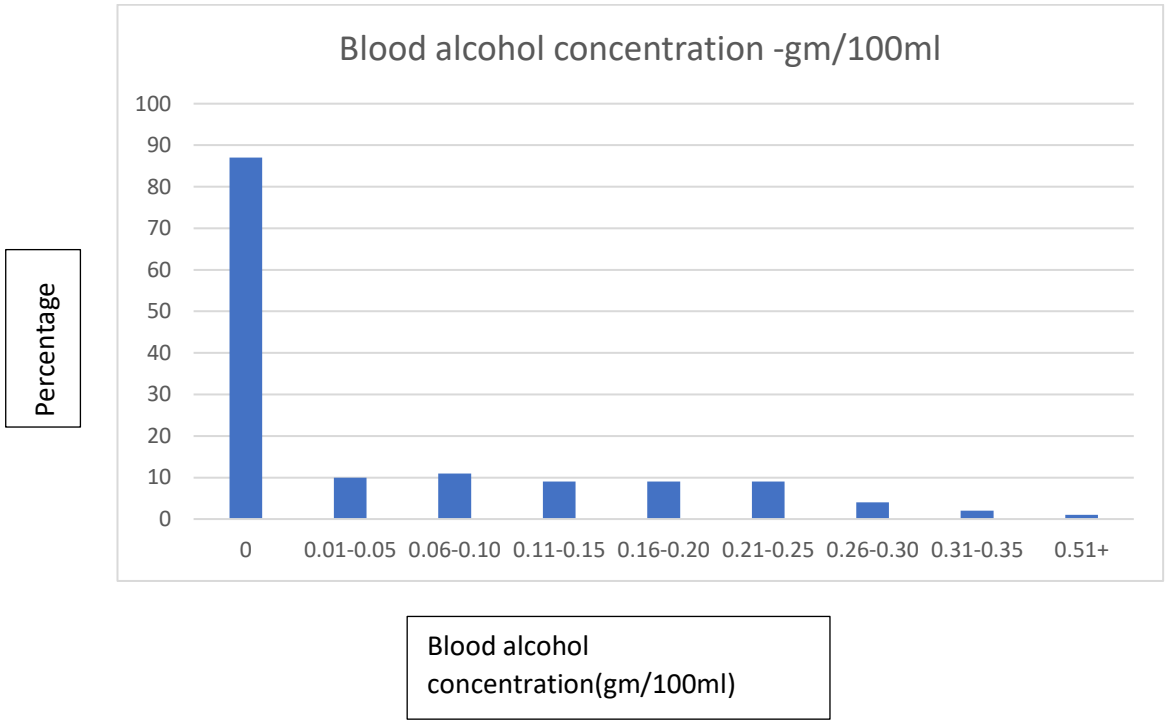


Fig 20: Blood alcohol concentration (gm/100ml) distribution in electrocution victims(%)

CHAPTER 5

Discussion

This retrospective descriptive autopsy-based study analysed all electrical fatalities admitted to three medicolegal mortuaries in eThekwini district, KwaZulu Natal, between 2006 and 2016. A total of 512 electrical fatalities were identified at postmortem during this study period. This exceeds the number of electrocutions in general, observed in Western Countries,[43,44,46,47-51] some observed over longer study periods,-[51] some Indian studies,[52,53] and South African studies.[24.57,58] As far as the author is aware, this is the first analysis of electrical fatalities within the metro and Kwa Zulu Natal. There are no autopsy-based statistics for rural electrical fatalities in South Africa.

Electrical fatalities in the eThekwini district rose steadily from 2006 to 2013, with a gradual decline from 2013 to 2016. The initial upward trend (2006 to 2013) mirrors that offered by the South African national and provincial reports rapid mortality surveillance for the proportion of unnatural deaths for the same period as this study. [72] The timeline of electrical supply and the powers outages is interesting in the context of this study time frame. The national load shedding crisis can be traced from the initial occurrence in October 2007 till December 2007, when peak load capacity was surpassed. Sporadic electricity disruptions were experienced between January to July 2008. Recession may have reduced electricity demand in 2009. Supply was relatively reliant until November 2014, when reserves and emergency measures failed. Electricity disruptions were a common occurrence in 2015.[32]The Iranian study conducted over a shorter time period, also reflected an upward trend.[56] The trend in eThekwini, KwaZulu Natal however, contrasts with that seen in Western Studies [46,47,50-], Indian studies and South African studies [57,58] conducted over varying study periods.

The average rate of electrocution fatalities over the 11 year period of study was 1,35/100 000 per year, and was higher than that seen in some Western countries over

varying study periods, of up to 40 years,[1,48-50,51] and in an Iranian experience[,,56,] The rate also exceeded that seen in Canada [43] North America[55] , India, and all South African studies.[24,57,58?,]However, the rate was lower than that in a national retrospective verbal autopsy based survey in Bangladesh conducted in 2000, and 2015 which showed a more than double rate in fatal electrocutions of up to 4,3/100 000 .[73] There are no autopsy based studies to confirm these deaths.

The Phoenix and Gale Street mortuaries were largely responsible for most electrocution cases during the study period. Individual mortuaries in eThekwini, however, have all admitted increasingly more electrocutions per year, post-2011, with Phoenix and Pinetown mortuaries accounting for most electrocutions in 2013. Between 2011 and 2013, the Phoenix mortuary admitted more cases than Gale Street mortuary. The upward trend in Phoenix for this period is paralleled by the greatest change in the number of electrocutions admitted to the Pinetown facility from 2012 to 2013. The Gale street mortuary serving the metro, on the other hand, had shown a steady, gradual rise in electrocutions.

The location of the Phoenix and Pinetown mortuaries allow for a catchment of cases from the urban, rural fringe. With disaggregation for area, it was noted that Phoenix, the suburb in which the Phoenix mortuary is situated, showed the lowest number of electrocutions overall. This indicates that the incidence of electrocutions is not defined by the location of the mortuary but rather its service areas.

Pockets of electrocution fatalities identify particular areas at risk. Tongaat, a suburb on the urban-rural fringe, admits cases to the Phoenix mortuary and showed the greatest number of electrocutions. Cato Manor and Sydenham which house informal settlements within the urban catchment, are subjects of case studies and media reports and expose a dire environment of illegal cables and cable theft.[30,31,76] This concurs with Von Caues's experience in the informal settlement of Khayelitsha,[58] but contrasts that seen in Johannesburg.[57]

Most fatal electrocutions occurred during the summer months in eThekwini, with the peak in December. The climate in eThekwini is sub-tropical, with hot, wet summers

usually extending from September to March and mild, dry winters.[132] and concurs with reason for increased summer electrocutions that have been documented.[3,25,92 133-135] with the exception of a Johannesburg study.[57]

Fatal electrocutions in eThekwini were found to occur during weekends predominantly and may be due to increased domestic activity or leisure activities or both. The inception of the ESKOM loadshedding crisis in South Africa at the time of the study may have been a plausible contributor to the fluctuating electricity supply. This may have increased the need for illegal acquisition of electricity or overloading of circuits. It is difficult however, to draw associations between the crisis and electrocutions due to lack of reliable timetables regarding loadshedding.[35]

The timing of fatal electrocutions in eThekwini is predominantly during the afternoon (12-17h59) except for the 20-39 year age group (06h00-11:59). In most cases, the time indicated on the SAPS 180 form indicates the police response time to the scene and not the time of death , unless witnessed. This may also suggest that electrocutions in the 20-39 year age category may have occurred before 06h00. This correlates with Blumenthal's finding of high voltage electrocutions between 00h00-06h00 in relation to possible cable theft.[24] The reason for electrocutions during early hours may involve cable theft or illegal wiring as poor visibility and detection may contribute to such activities. Childhood electrocutions occur predominantly during 12h00 -17h59 with the 0-9 years of age being the most susceptible at this time.

Illegal connections accounted for almost half of all documented electrical sources associated with electrocutions. This is likely an underestimation of the true number of cases. Electrocutions associated with illegal connections in eThekwini exceeded those seen in discussed studies, internationally[56] and all South African studies on electrocution.[24,57,58] Typical victims of electrocutions were males in the third decade of life, with a mean age of 25 years. This concurs with provincial electrocution statistics,[24,25,57,58] and electrocution findings in international studies,[1,3,49-54]In contrast to studies where the majority of deaths occur when working with electrical sources, reports in South Africa have shown that circumstances for electrocution, such as illegal

connections and cable theft may account for a large number of electrocutions in this age group.[24,25,57,58.]

Children accounted for a third of all cases due to illegal connections, with 19 fatalities being under ten years and the youngest victims being under 1 year of age. This contrasts the experience in Gauteng and Cape Town which showed a predominantly adult male casualty associated with practice.[24,58]

The highest percentage of electrocution fatalities in this study, in fact, involved those under the age of ten years (28,7%), with 21,5% of all electrocutions occurring in the 0-5year age group (n=110 victims). Within this age category, the two year olds were most vulnerable (20,41% of under 10years) In comparison, the fatalities under 10 years was slightly less than that in a Turkish study by Tirasci[2] but exceeded that seen in the under 10 years in India,[3] Turkey,[11] and the Cape Town study[58], all of which also showed fewer electrocutions overall. The findings in this study concurred with NIMSS and by Matthews et al., who noted a high incidence of electrocutions in under-fives in eThekwini. [61,62]

This study showed that the highest percentage of female electrocution fatalities were under the age of 10 years (43,1%), which contrasts international studies.[73] Overall, the average age of female electrocution fatalities was younger than that of males (19 versus 23,4 years).

The anatomical distribution of injuries seen in this study reflects those seen in most studies on electrocution fatalities,[2,3,27,.80.83,87,89] with the upper limbs being most affected (48,63%), followed by limbs, chest and feet followed in descending order. Typical joule burns were detected in 63,5% of cases. and is comparable to most studies on electrocution,[48,] although almost double than that seen in the Iranian study.[56] Entry and exit wounds were not specified. In contrast to the right hand being predominantly affected in most studies,[27.55,56] both hands were equally affected in this study (24%). Joule burns related to illegal connections in adults. also affected the hands in an equal frequency(15) followed by the left lower limb (11) excluding the foot, then the chest

(10) and the right arm (7). Stratification of injuries under 5years of ages mirrored that of adults and also showed predominantly injuries of extremities, an upper arm predominance, and with single injury stigmata (47,27%). Similarly, joule burns associated with illegal connections followed this trend and general anatomical distribution of injuries seen in other documented studies in electrocution. [2,3,27,.80.83,87,89] The presence of joule burns on hands in children implies either an active reach to electrical connections including illegal connections or these being in close proximity to the child's area of movement. There were no oral injuries documented in this study.

Illegal connections accounted for the greatest source of electrocutions in eThekwini, KwaZulu Natal. As far as national studies, this source of electrocution accounts for the greatest number of electrocution cases documented. This confirms sentiments of raising concerns regarding this source that have been echoed in other studies[24,57,56,58.] Although this study did not differentiate between high and low voltage injuries, it may be noted that there were no specific differences in source and presentation at autopsy to distinguish illegal connections or cable theft on the basis of voltage. This concurs with findings by Blumenthal who observed that voltage and presentation at postmortem is not mutually exclusive.[24]

Other non electrical injuries at autopsy included predominantly burns, 3 cases of which were complicated during a hospital stay by sepsis, and blunt force injuries including abrasions, lacerations and fractures This concurred with the findings of non electrical injuries in other studies.[24,57,58] Although stigmata of the initial electrocution were not evident at postmortem, clinical documentation of between 30-70% surface burns were attributed to witnessed accounts of electrocution in this study. The dilemma for the forensic pathologist is two-fold in this regard; unless there is a documented history of electrocution, such cases may easily be concluded as complications associated with burns, and due to a healing period or intervening sepsis, joule burns may not be recognised as such at postmortem. It is therefore acknowledged that electrocutions may be missed or classified as burns. This has been documented in other studies. [43,44,] In two cases, natural cardiac disease was documented but not considered contributory to the cause of death.

Histology taken in 85 cases in this study , of which only 6 cases were reported, 3 of which confirmed electrocutions. Reports conclusive of electrocutions did not detail histological findings as recorded in other South African studies. [24,58] Nevertheless, all three cases were associated with a positive history of electrocutions. Furthermore, most electrocutions in this study were concluded in the absence of histology, either macroscopically with the presence of stigmata or based on history. This is sentiment shared in other studies.[24,57,58] The value of histology, apart from what appears to be an academic exercise, is questionable. Depending on time, resources and workload it may be appreciated that findings at autopsy, in most cases, in this study were enough to conclude electrocution confidently without the need for histological confirmation.

Blood alcohol was taken for just under half the number of cases in this study (47,66%). Results were indicated for 58% of these cases. Most of these victims had no alcohol detected in blood (61%) correlating with findings done in other studies.[24] The mean blood alcohol level for those with a positive test was 0.16gm/100ml and were predominately males. In South Africa legal blood alcohol limit for driving is 0,05gm/100ml.[66] There is an association between alcohol and behaviour, but the association with electrocution has not been assessed.[66] Whilst this may have implications in an occupational setting, it was not possible to comment on the association between alcohol use and electrocution risk in this study as there was poor documentation of the place of occurrence. The absence of alcohol in some cases, or in those where levels were less than 0,05gm/100ml, made the victims no less immune to electrocution. In the same vein, the presence of a maximum blood alcohol concentration of 0,55gm/100ml in this study can cause acute alcohol intoxication in itself, and yet presented as an electrical fatality. Alcohol may reduce reaction time but must be considered given other factors, such as alcohol tolerance , sample collection, analysis, and synergistic drug use. The association between alcohol and electrocutions warrant further studies.

In comparison to other studies in South Africa,[24,57,58] there was no indication in the postmortem reports to hypothesise on the manner of death in electrocution fatalities in eThekwini.

CHAPTER 6

CONCLUSION

Electrocutions account for significant fatalities in eThekwini and have shown an increasing trend in the years of study. Children under 10 years, especially females, and young adults constitute the greatest number of victims. High-risk areas for electrocution have been identified on the urban-rural fringe and within the metro.

This study demonstrates the importance of understanding the regional demographics in electrocution deaths. A key to this is the standardisation of death scene protocol reporting and the training of forensic pathology officers to be aware of scenarios in which these deaths are likely to occur and drawing awareness to the magnitude of the problem regionally and provincially. Pulsed education drives and campaigns are required to make the general public aware of the dangers of electricity. The effort is multidisciplinary.

This study over an 11 year period found that there was a dramatic increase in electrocution deaths. There was a significant higher incidence in males than females. However, in addition, a bimodal age distribution showed that children under 10 years constituted a high risk group with females being more susceptible. Most deaths occurred on weekends and during summer. The commonest period of these electrocutions was between 12-18h00. Factors identified that may be contributing to this increase are illegal wiring and cable theft.

Fatal electrocutions are preventable. A single death is a death too many.

As far as the author is aware, this is the first study of the demographics of electrocution deaths in eThekwini, KwaZulu Natal.

CHAPTER 7

Recommendations

Deaths by electrocution continue to elude the forensic pathologist. In the absence of pathognomonic findings, a crucial part of determining or inferring death is based on scene investigation.

It is not always possible for forensic pathologists in South Africa to attend every crime scene. For this reason, training of crime scene investigators and forensic pathology officers to be more observant of such deaths is recommended. A standardised protocol or template in the investigative process, similar to that used in sudden infant deaths, may help to draw a more comprehensive overview of the circumstances and allow for comparisons in terms of trends.

In this study, the maximum number of deaths related to illegal wiring or cable theft were not established due to poor scene documentation, despite these factors being a significantly contributory to fatalities seen. High risk domestic environments may infer a home setting but the cause for electrocution may be different. Failure to indicate the voltage in electrocutions makes it difficult to institute preventative measures an electrical socket in the home as well as a free lying illegal cable are domestic hazards with completely different clinical consequences. Prevention models and protocols as a result, also differ.

There are no autopsy based studies on fatal electrocutions in the workplace as far as the author is aware. In view of the existing literature discussed, it is recommended that further studies explore this circumstance in eThekwini.

The above are obstacles to formulating focused preventative drives that may be unique to the community served.

Statistical coding of electrocution deaths as a single entity alone needs examination. Statistics regionally, provincially and nationally have diluted such deaths under broad categories that prevent actual trends from being identified. Many such deaths are unaccounted for. The process requires education of not only the forensic pathology community but also data capturers. The exercise is a multidisciplinary one.

The forensic pathologist plays a crucial role in social risk reform. This is not an isolated venture. The impact of the child death review process is evident[74] and should encourage intervention directed towards electrocutions, burns etc. The preventative measures of such deaths call for directed strategies. Active liaison with community leaders and employers in identifying risks may ensure that prevention measures are successful.

Electrocution deaths call for more prospective studies in view of increasing electrification.

CHAPTER 8

Limitations

The incomplete capturing of data in eThekwini mortuaries, most of which was paper based, prevented not only comparison of electrocution deaths against all unnatural deaths regionally, but provincially and nationally. The prevalence of electrocutions using regional and national data such as census, provide only a point in time glimpse of the problem and do not provide an indication of trends. Importantly, admission data from mortuaries were missing in databases and therefore could not be appraised against population growth in eThekwini. The number of electrocution cases identified therefore, account for the minimum total of all such deaths in eThekwini.

The poor documentation at the scene made it difficult to delineate domestic and occupational environments as well as voltage type. This is crucial to highlight areas of risk to electrocution. Particularly in cases of electrocution, where the scene findings are crucial to conclusions, the value of such practice in eThekwini has been sorely undermined.

Although loadshedding was expected to have played a role in electrocutions, lack of concrete baseline data from ESKOM was not available to identify trends.

Ancillary investigations including histology and blood alcohol concentrations were documented in limited cases. The benefit of such ancillary investigations in concluding such cases has been discussed. Many cases of histology were not reported on. The practice of taking histology in confirmed cases of electrocution may be useful in contributing to repository of findings in electrical fatalities in general,

however it is neither pathognomonic or exclusive and must be weighed against time and resources.

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Poor participation by eThekwini mortuaries in provincial trend identifiers, like NIMSS made it difficult to compare electrocutions with those in other provinces that provided electrocution demographics.

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