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A retrospective descriptive study of electrocution deaths in Gauteng, South Africa: 2001–2004

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ABSTRACT

There is a paucity of data with regards to non-lightning, electrical-related injuries in sub-Saharan Africa. A review of the South African medical literature also shows a dearth of electrocution-related information. This study aimed to retrospectively review all high- and low-voltage-electrocution-fatality cases in Gauteng, South Africa for the period 2001–2004. Altogether, 126 electrocution-related deaths were identified, of which 91 cases represented low-voltage-electrocution deaths and 35 represented high-voltage-electrocution deaths. All cases were reviewed from a demographic and pathology-of-trauma point of view. This study serves to illustrate the high number of electrocution-related fatality cases in the region as compared with the rest of the world. It also serves to highlight the need for more active research and attention in this field.

1. Introduction

A review of the South African medical literature shows a paucity of research into electrocution-related deaths. In fact, a review of the international literature shows almost no information from any sub-Saharan country regarding non-lightning, electrical-related injuries.

This study aimed to retrospectively review all electrocution-fatality cases in the Gauteng province of South Africa between 2001 and 2004. Furthermore, this study also aimed to focus not only on the demographics of electrocution-fatality cases, but also on the 'pathology-of-trauma' related to electrocution-fatality cases in the region.

South Africa is considered to be a developing country and is currently estimated as having a population of 48.7 million inhabitants. Life expectancy at birth is estimated at approximately 50.3 years for males and 53.9 years for females.

Gauteng is the smallest province in South Africa, occupying an area of 17 010 km^2, approximately 1.4% of the land area (see maps). Despite this, Gauteng has the largest share of the South African population. It accommodates almost 19.7% of the total South African population. It is inhabited by people of different cultural backgrounds from all provinces and also from other countries.

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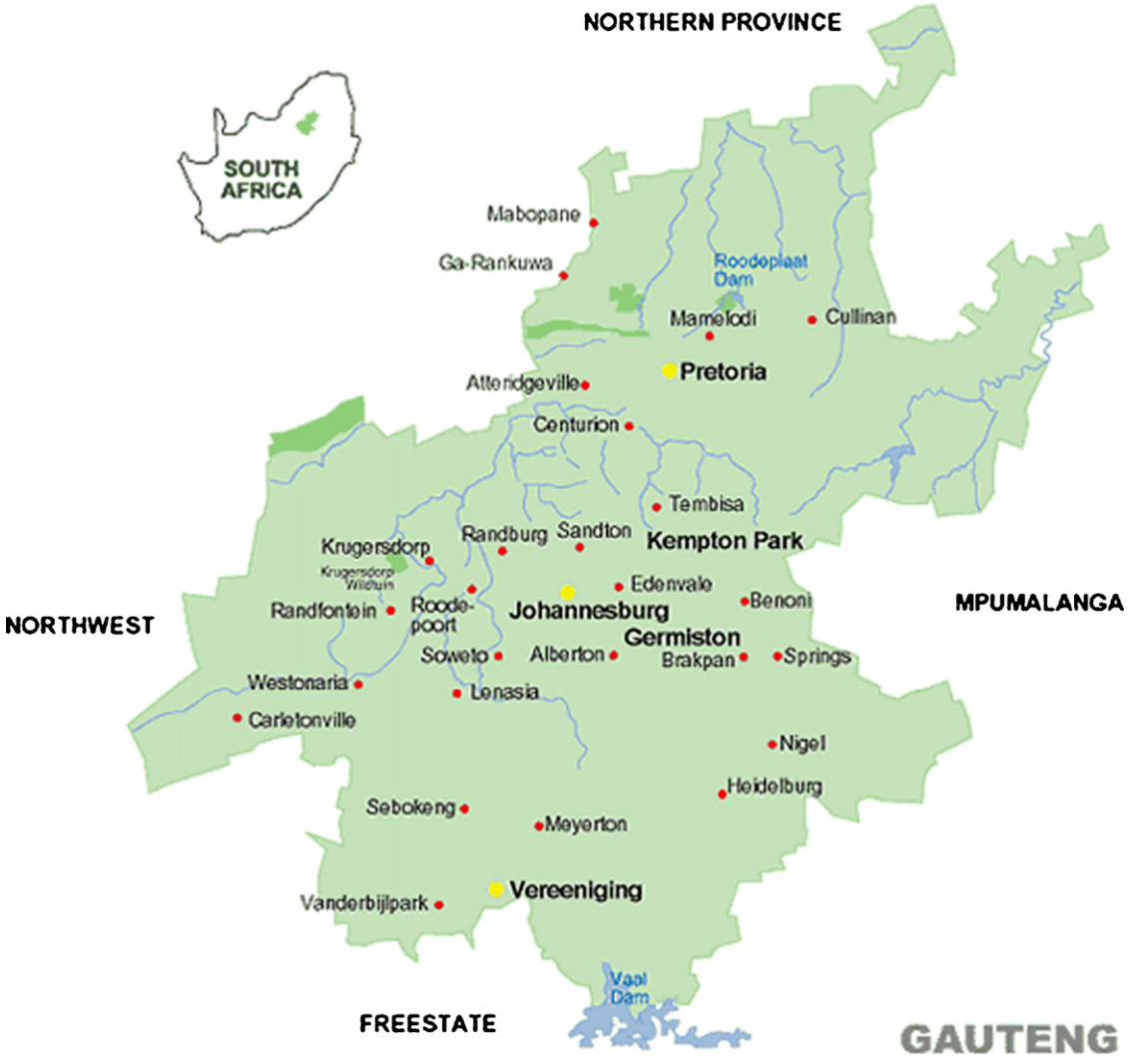
Map of South Africa showing the provinces

Approximately 10.5 million people (21.5% of the population) live in the province. According to the Development Bank of Southern Africa, Gauteng had an estimated total population of 10 609 159 when surveyed during the period between 1996 and 2006. The population of Gauteng, according to the 2001 census, showed that approximately 74% of the population was black African followed by the white population at 20%, coloured population at 4% and Indian/Asian at 3%. Fifty-two percent of the South African population is female.

As regards the population of Gauteng: nearly one-third (32%) of the population is younger than 15 years and approximately 7% (3.5 million) is aged 60 years or older. Of those younger than 15 years, approximately 19% (2.94 million) live in Gauteng. Males make up the larger proportion of the population, and Gauteng is the only province in the country where males predominate. Gauteng has the highest proportion (96%) of residents living in urban areas.

The source of energy for domestic use is one of the indicators of development and service delivery. A total of 89.9% of households in Gauteng used electricity from the mains for lighting. The use of electricity for cooking purposes followed this pattern among various communities: a total of



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80.4% of the households headed by black Africans, 87.5% of the households headed by coloureds, almost all households headed by Indian/Asian (99.6%) and all households headed by whites (98.9%). In Gauteng, 79.5% of households used electricity from the mains for heating purposes [1,2].

Most households in South Africa are supplied electricity by the South African Electricity Supply Company (ESKOM). On an average, each household has a voltage of 240 V (220 V) which is supplied as alternating current of 50 Hz. However, illegal supply of electricity does exist in certain areas of South Africa [3].

The Inquest Act (Act 58 of 1959) requires that all unnatural deaths be referred for medicolegal autopsy examination in South Africa. An unnatural death under South African law is defined as follows:

- any death due to a force, direct or indirect, with or without complications, or any death due to a chemical and/or poison, with or without complication;
- any death due to an act or omission, on the part of any person;
- any death that occurs under the influence of an anaesthetic agent (as contemplated in section 56 of the Health Professions Act of 1974) and
- and any sudden, unexpected or frankly suspicious death.

South Africa has approximately 60 000–80 000 unnatural deaths per year, with an average of approximately 70 000 per year. There are currently 36 registered forensic pathologists in South Africa. An electrocution death is considered an unnatural death and is, therefore, referred for autopsy examination in South Africa.

Numerous retrospective studies on electrocution-related deaths have been performed at other centres around the world. It is uncertain how South Africa compares to these centres [4–10].

Nearly all electrocution fatalities are non-intentional, while some are suicidal and a few are homicidal. Judicial electrocution cases do not exist in South Africa. Electrocution-torture cases are also rare. Carelessness, misuse or improper maintenance of electrical equipment represent the chief reasons for non-intentional, electrocution worldwide [11–14].

It is also well known that numerous deaths result from the theft of electric utilities, and there is little published literature regarding high-voltage electrocution deaths. The reasons for this cable theft remain speculative. There is little formal data available to support these claims and most reports of cable theft come from the lay press and media in South Africa [15].

Routine safety inspections are generally not performed in homes in South Africa, despite the fact that there is express legislation regarding wiring and electricity. General points to look for when making an inspection would be breakages, wear/deterioration, signs of overheating, missing parts (screws, switches), faulty appliance controls, doors not closing smoothly or adequately, incorrect labelling of electricity requirements and loose fixtures or fittings [16,17].

Estimates vary among authors, but it is generally considered that the passage of a current of 50–80 mA across the heart for more than a few seconds is likely to cause death [18]. As stated, currents sustained for some seconds at over 50–80 mA carry a substantial risk of death.

Electrocution injuries typically involve the skin; however, vascular lesions, muscular injuries, liver, bone, neuropathological and eye changes have also been recorded [19–22].

Multiple potential risk factors exist in victims of electrocution, such as decreased skin resistance because of wet extremities and underlying heart disease.

2. Materials and methods

For the purposes of this study, a low-voltage-electrocution-related death was defined as the passage of a substantial electrical current at a voltage of less than 1000 V through the body, which directly or indirectly resulted in the death of the individual. A high-voltage-electrocution-related death was defined as the passage of a substantial electrical current through the human body at a voltage greater than 1000 V, from a man-made device, which resulted in the direct or indirect death of the individual. Lightning-related deaths were excluded from this study. High-voltage and low-voltage deaths were recorded on the SAP180 form by the attending investigating officers at the scene of death. Therefore, all possible and probable electrocution-related fatality cases referred to the seven large medicolegal laboratories in Gauteng were identified for this study.

Official data were collected from the large medicolegal laboratories in Gauteng, namely: the medicolegal laboratories of Pretoria, Medunsa, Bronkhorstspruit, Johannesburg, Diepkloof, Germiston and Roodepoort. Electrocution deaths were identified through the National Injury Mortality Surveillance System (NIMSS) programme, which was instituted in South Africa in June 1998 [23].

Data were processed using the SAS, version 8, a statistical software package, and were analysed with the assistance of a statistician from the University of Pretoria.

Access to and consent for use of the data was obtained from the Gauteng Department of Health, The University of Pretoria's Faculty of Health Sciences Ethics Committee, the South African Police Service (SAPS) authorities and individual mortuary managers. All data were treated confidentially.

3. Results

In total, 126 electrocution-related deaths were identified by the NIMSS programme in Gauteng for the time period between 1 January 2001 and 31 December 2004. There were 91 and 35 cases, respectively, of low- and high-voltage-electrocution-related deaths.

4. Low-voltage-electrocution deaths

There were 91 cases of low-voltage-electrocution-related deaths in Gauteng between 2001 and 2004.

The breakdown as per mortuary reports is as follows: Pretoria, 27 cases (29.67%); Medunsa, two cases (2.2%); Germiston, 24 cases (26.37%); Johannesburg, 17 cases

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Table 1 – Number of low-voltage incidents based on seasons in the year.

DJF	31
MAM	18
JJA	17
SON	25

Low voltage-electrocution deaths ($n = 91$).

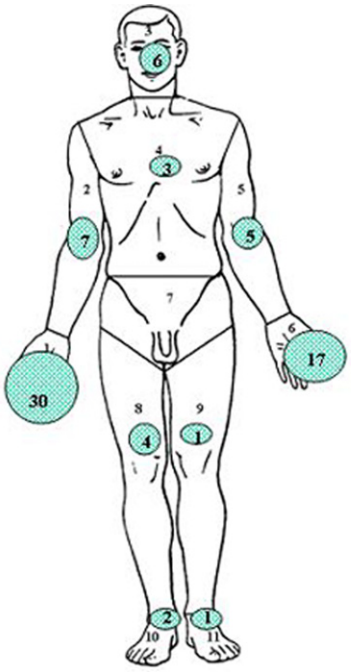
(18.68%); Roodepoort, 8 cases (8.79%) and Diepkloof, 13 cases (14.29%). Interestingly, Bronkhorstspruit mortuary had no relevant cases for that time period.

The breakdown as per race, gender and age is as follows: Asians – two (2.20%), blacks – 71 (78.02%), whites – 16 (17.58%) and mixed-ethnic descent – two deaths (2.20%). Of the fatalities, 69 were male (75.82%) and 22 were female (24.18%). The fatalities included 35 cases younger than 25 years (41.67%); 46 cases aged between 26 and 50 years (54.76%) and three in the age group between 51 and 75 years (3.57%).

Seasonal variation of injury and death (see Table 1): Summer (DJF) 31 (34.07%), Autumn (MAM) 18 (19.78%), Winter (JJA) 17 (18.68%) and Spring (SON) 25 deaths (27.47%). Summer (DJF) 32 (35.16%), Autumn (MAM) 18 (19.78%), Winter (JJA) 17 (18.68%) and Spring (SON) 24 deaths (26.37%).

Location and manner of death: Sixty-nine (78.41%) of the deaths occurred indoors and 19 (21.59%) of the deaths occurred outdoors. All cases were considered non-intentional, except for two (2.27%) which were deemed suicidal.

Fig. 1 demonstrates the chief area of wounding for low-voltage injuries. (The chief area of wounding was defined as the external anatomical body area that received, according to the author, the most severe tissue injury.) The frequency of



Chief area of wounding	1	2	3	4	5	6	7	8	9	10	11
Frequency	30	7	6	3	5	17	0	4	1	2	1

Fig. 1 – Chief area of wounding as per anatomical location on the body for low-voltage fatality cases ($n = 91$).

Table 2 – Histological changes in low-voltage cases.

	Low voltage ($n = 91$)
Vacuolisation	7 cases (7.69%)
Metallisation	2 cases (2.20%)
Streaming	9 cases (9.89%)
Eosinophillia	2 cases (2.20%)

Please note that histology was only performed in nine of the low-voltage cases.

missing data is 15. Electrothermal injury was well defined in 43 cases (47.25%). Blister formation was noted positively in 20 of the cases (21.98%) (see Table 2).

Vacuolisation (microscopically, the forming of spaces or cavities within cells): histological examination was only performed on nine cases, and seven (7.69%) reported vacuolisation.

Metallisation (trace evidence deposit of metallic electrode on the skin surface) was reported in two cases (2.20%).

Streaming ('combed' appearance of the nuclei of the stratum basalis) was reported in nine (9.89%) of the histology cases. Eosinophilia was reported in two (2.20%) of the cases. Alcohol reports were only found in four of the case dockets (0.03 g, 0.11 g, 0.15 g and 0.29 g per 100 ml). CPR was performed in 15 of the cases (16.48%).

Twenty-two cases (24.18%) had some form of associated blunt-force trauma. Sixty-seven cases (73.63%) had no burns, two cases (2.20) had first-degree burns, 20 cases (21.98%) had second-degree burns, one case (1.10%) had third-degree burns and one case (1.10%) had a 'crocodile-skin' appearance. Four cases had some sort of underlying natural disease. Possible pathway of current through the body: unknown – 30 cases (32.97%); through the chest – 58 cases (63.74%); through the head – 3 cases (3.30%). Of the 91 cases, 79 cases (86.81%) were not witnessed, while 12 cases (13.19%) were witnessed.

5. High-voltage-electrocution deaths

There were 35 cases of high-voltage-electrocution-related deaths in Gauteng for the period 2001–2004.

The breakdown as per mortuary is as follows: Pretoria, eight (22.86%); Medunsa, one (2.86%); Germiston, two (5.71%); Johannesburg, 14 (40.00%); Diepkloof, one (2.86%); and Roodepoort, nine cases (25.71%). Interestingly, Bronkhorstspruit mortuary had no relevant cases in that time period.

The breakdown as per race, gender and age is as follows: blacks, 25 deaths (71.43%); whites, seven deaths (20.00%); and Asians and mixed-ethnic descent, three deaths (8.57%). Of the dead, 32 (91.43%) were male and three (8.57%) were female. Six (19.35%) were younger than 25 years; 21 (67.74%) were between 26 and 50 years of age; three (9.68%) were in the age group 51–75 years and one case (3.23%) was in the age group 76–100 years.

Table 3 presents the seasonal variation of injury and death: Summer (DJF) 10 (28.57%), Autumn (MAM) nine (25.71%), Winter (JJA) eight (22.86%) and Spring (SON) eight deaths (22.86%). Four (11.43%) of the deaths occurred indoors and 31 (88.57%) occurred outdoors. All cases were non-intentional except for one case (2.94%), which was suicidal.

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Table 3 – Number of high-voltage incidents based on seasons in the year.	
DJF	10
MAM	9
JJA	8
SON	8
High-voltage-electrocution deaths ($n = 35$).	

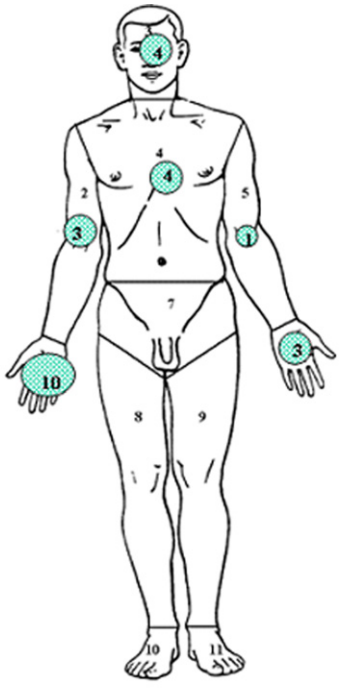
Table 4 – Histological changes in high-voltage cases.	
	High voltage ($n = 35$)
Vacuolisation	1 case (2.86%)
Metallisation	0 cases
Streaming	1 case (2.86%)
Eosinophilia	0 cases
Please note that histology was only performed in two of the high-voltage cases.	

Fig. 2 demonstrates the chief area of wounding for high-voltage-related injuries. (The chief area of wounding was defined as the external anatomical body area that received, according to the author, the most severe tissue injury.) The frequency of the missing data is 10.

Two of the cases (5.71%) had findings which were interpreted in the post-mortem reports as being characteristic of an electrothermal injury. Blister formation was noted in four cases (11.43%) (Table 4).

Only one case (2.86%) was reported to have had vacuolisation (microscopically, the forming of spaces or cavities within cells). None of the cases reported metallisation (trace evidence deposit of metallic electrode on the skin surface). One of the cases (2.86%) reported streaming ('combed' appearance of the nuclei of the stratum basalis). None of the cases reported eosinophilia. Alcohol reports were only found in two of the case dockets (0.02 g and 0.29 g per 100 ml). CPR was performed in seven of the cases (20.00%). Thirteen cases (37.14%) reported some form of associated blunt-force trauma. Three cases (8.57%) had no burns and/or no reported burns, three cases (8.57%) had second-degree burns, 22 cases (62.86%) had third-degree burns, four cases (11.43%) had fourth-degree burns and three cases (8.57%) were reported as having crocodile skin. One case (2.86%) had some sort of underlying natural disease.

Six of the cases (17.14%) had associated long-bone fractures. Five of the cases (14.29%) had associated (non-surgical/surgical) limb amputations. Five of the cases (14.29%) were reported as having burned and/or singed their hair. Possible pathway of current through the body: unknown – 19 cases (54.29%); through the chest – 15 cases (42.86%) and through the head – one case (2.86%). Of the cases, 29 cases (82.86%) were not witnessed, while six cases (17.14%) were witnessed.



Chief area of wounding	1	2	3	4	5	6	7	8	9	10	11
Frequency	10	3	4	4	1	3	0	0	0	0	0

Fig. 2 – Chief area of wounding as per anatomical location on the body for high-voltage fatality cases ($n = 35$).

6. Discussion

This study did have its shortfalls in that there was a great disparity in medicolegal reporting between the different medicolegal laboratories. It was impossible to ascertain, for example, precisely how many electrocution cases occurred on duty, the professions of those electrocuted, or the exact circumstances under which many of these electrocution cases occurred. It was difficult to determine from the available records how many of the electrocution cases led to civil litigation and the quantum of said litigation. Histology was not performed in all cases [25–28] and blood toxicology was not performed in all the cases.

However, this study did serve to highlight certain points:

First, this study served to show that electrocution deaths constitute a serious problem in South Africa: The Texas study showed 185 cases in 30 years [6]. The Adelaide study showed 96 cases in 30 years [7]. The New Delhi study showed 153 cases in 6 years [8]. The Swedish study showed 285 cases in 15 years [12]. This study showed 126 cases in 4 years. Gauteng showed 91 (0.17%) low-voltage-electrocution-related and 35 (0.06%) high-voltage-electrocution-related deaths for the 51 104 unnatural deaths recorded over the specified 4-year time period.

Second, this study served to illustrate that the pathology-of-trauma resulting from electrocution deaths is complex and may be difficult to interpret in some scenarios. The need for greater attention to detail regarding the medicolegal investigation of electricity-related deaths in South Africa, with standardised protocol implementation, is needed. This study served to illustrate that more detailed studies in this field need to be undertaken in the future.

The findings with regards to the pathology-of-trauma resulting from high- and low-voltage-electrocution deaths were generally in keeping with the reports in the international literature [4,–10,24].

In this series, low-voltage electrocution tended to take place indoors, whereas high-voltage electrocution tended to

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take place outdoors ($p < 0.0001$). Pathognomonic electrothermal injuries, specifically the so-called 'Joule burn', was more prevalent in the low-voltage series ($p < 0.0001$).

From this series, it would appear that high-voltage-electrocution deaths caused deeper burn wounds than low-voltage-electrocution deaths ($p < 0.0001$). Fractures were more commonly associated with high-voltage-electrocution deaths ($p < 0.0001$). Amputations (surgical/non-surgical) were more commonly associated with high-voltage-electrocution deaths ($p = 0.0002$). Information with regards to the mechanism behind the fractures and the amputations was difficult to interpret from the available information.

Singeing of hair was more commonly associated with high-voltage-electrocution deaths ($p = 0.0002$). Once again, the mechanism behind the singeing of hair was difficult to interpret from the available information.

Determination of the histological appearances of the wounds are rather controversial, as some changes formally claimed to be specific for electrical lesions have been shown to be thermal in nature. According to Bernard Knight, there is little that is absolutely pathognomonic of electrical, as opposed to purely thermal, burns [18].

This study also demonstrated that most high-voltage deaths occurred at night (1800–0000 h) or in the early hours of the morning (0000–0600 h). This finding was of interest and contrary to the findings in the literature, which state that high-voltage deaths usually occur during the daylight hours [15]. This finding would be in keeping with media reports, suggesting after-hour theft of electricity utilities.

7. Conclusion

At the outset, this study serves to highlight that electrocution-related deaths constitute a serious problem in South Africa.

Second, this study serves to illustrate that the pathology-of-trauma resulting from electrocution deaths is complex and may be difficult to interpret in some scenarios. A call is, therefore, made for greater attention to detail regarding the medicolegal investigation of electricity-related deaths in South Africa, with standardised protocol implementation and better reporting.

Finally, this study calls for multidisciplinary attention and awareness regarding electrocution-related fatality cases, both globally and in the South African context.

Conflict of interest statement

There are no conflicts of interest with any regard that could inappropriately influence the work.

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