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An audit of blunt head injuries sustained by children up to 10 years of age admitted to Chris Hani Baragwanath Academic Hospital

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An Audit of Blunt Head Injuries Sustained by Children up to 10 years of Age Admitted to Chris Hani Baragwanath Academic Hospital

Vered Lack

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A dissertation submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree Master of Medicine

Declaration

I, Vered Lack (student number 9402066y), declare that this research report is my own unaided work. It is being submitted for the degree of Master of Medicine in Paediatric Surgery at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted previously for any other degree or examination at any other University.

Signed on this 24th day of October 2021 in Johannesburg.

Dedication

I dedicate this work to Dorian my loving husband and steadfast rock, and wonderful children Rebecca, Joshua and Sarah. Their unwavering encouragement and support made all of this possible.

PRESENTATIONS ARISING FROMTHIS STUDY

21/06/2018 Electrical burns in Soweto Children: Unanticipated casualties of improvisation. SRS (Surgical Research Society) South Africa. Mthatha, Walter Sisulu University, Eastern Cape, SA.
Podium Presentation

19/07/2018 Electrical burns in children living in a South African township: casualties of improvised electricity access. BAPS/BAPES 65th Annual International Congress. AECC, Liverpool, UK.
Podium presentation

25/08/2018 Electrical burns in Soweto children. SAAPS (South African Association of Paediatric Surgeons) Conference 2018. University of Pretoria, Hatfield campus. Pretoria, SA.
Podium presentation, 2nd prize awarded

28/11/2018 Electrical Injuries in Soweto children: unanticipated casualties of improvisation. Bert Myburgh Research Forum. Len Miller Lecture theatre, Department of Surgery, Wits Medical School, Johannesburg, SA.
Podium presentation

15/06/2019 Quantifying the impact of South African township environments on paediatric trauma. EUPSA Congress 2019. Crowne Plaza Hotel, Belgrade, Serbia.
Poster presentation

05/07/2019 The spectrum of traumatic head injuries as experienced by children living in a South African township. BAPS 66th Annual International Congress. East Midlands Conference Center, Nottingham, UK.
Poster presentation

21/09/2019 The impact of South African township environments on paediatric trauma. 51st Annual Meeting of the Canadian Association of Paediatric Surgeons (CAPS). Quebec City, Quebec, Canada.
Podium presentation

22/11/2019 The epidemiology of head-injured children admitted to Chris Hani Baragwanath Academic Hospital. SAAPS 2019. Century City Conference Centre, Cape Town, SA.
Podium presentation

PUBLICATIONS ARISING FROM THIS STUDY

Lack V, Esteves M, Nnaji LU, Loveland JA, Westgarth-Taylor C. The epidemiology of paediatric electrical injuries in a South African township. Burns Open. 2020;4(2):53-9.

Lack V, Fru P, van Rensburg K, van Rensburg C, Loveland J. The epidemiology of traumatic brain injuries sustained by children under ten years of age presenting to a tertiary level hospital in Soweto. Accepted 1 March 2021: South African Medical Journal (Ref: SAMJ15553) for publication in August 2021

Mashavave N, Withers A, Gabler T, Lack V, Harrison D, Loveland J. A 7-year retrospective review of renal trauma in paediatric patients in Johannesburg. Accepted April 2021 South African Journal of Surgery (Ref: SAJS 3196)

ABSTRACT

Background. Traumatic brain injury (TBI) in the paediatric population is a significant contributor to death and disability worldwide. In Sub-Saharan Africa death and disability from TBI is still superseded by infectious disease. Mechanisms of injury differ by region and socio-economics, but in general falls, road traffic collisions (RTC), being “struck by/against objects” and non-accidental injuries (NAI) are responsible for most injuries.

Objectives. To quantify the burden of TBI in terms of demographics, causes and severity. To explore resource utilisation regarding length of stay, computed tomography (CT) brain scan use, and multidisciplinary participation. To interrogate possible temporal patterns of injury. Thus, to identify potential targets for community-based prevention strategies.

Methods. A 5-year retrospective review for all children under 10 years admitted with TBI between September 2013 and August 2018. Demographics, date of injury, mechanism of injury, severity of TBI based on Glasgow Coma Scale, and requirement for CT brain were collected for each patient. Outcomes were reported as discharge, transfer or death. Outcomes for children sustaining isolated TBI were compared to those sustaining TBI with polytrauma.

Results. A total of 2 153 patients were included, with mean (SD) age of 4.6 (2.7) years and male to female ratio 1.7:1. RTC was the most frequent category at 59% (80% of these were pedestrian collisions), followed by falls at 24%. Mild TBI accounted for 87% of admissions, 6% moderate, and 7% severe injuries. Polytrauma was associated with increased severity of TBI. The cohort carried a 2.3% mortality. NAI accounted for 6% of injuries and carried a 4% mortality. Median (IQR) hospitalisation was 1 (1-3) days, ranging from less than 24 hours to 132 days. CT scans were performed on 43% of admitted patients and 48% of patients were consulted by another medical or allied medical discipline. Injuries were more frequent in summer months and on week-ends. Infants under a year of age were identified as a group particularly vulnerable to injury, specifically NAI.

Conclusion. Paediatric TBI was demonstrated to be a resource intensive public health concern. From the results we identified potential primary prevention targets that could perhaps be incorporated into broader community-based intervention

programs. We also identified a need to further study long-term consequences of mild TBI in our paediatric population.

ACKNOWLEDGEMENTS

Many thanks to my supervisors Professor Jerome Loveland and Dr Pascaline Fru for their support and guidance. I extend my gratitude to all the nursing staff at Chris Hani Baragwanath Academic Hospital for their commitment and dedication to the patients and to their record keeping, integral to the functioning of this institution. Last but not least, thank-you to my family and friends who cheered me on.

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LIST OF ABBREVIATIONS

ATLS: Advanced trauma life support

CHBAH: Chris Hani Baragwanath Academic Hospital

CI: Confidence interval

CT: computed tomography

GCS: Glasgow coma scale

HI: Head injury

IQR: Interquartile range

MVC: motor vehicle collision

NAI :non-accidental injury

NICE: National Institute for Health and Care Excellence

RTC: road traffic collision

SD: Standard deviation

TBI: traumatic brain injury

THINK: Traumatic Head Injury: Neurocognitive assessment in Kids

UK: United Kingdom

CHAPTER 1 INTRODUCTION

1.1 Background

Traumatic brain injury (TBI) in the paediatric population is a significant contributor to death and disability worldwide. It is estimated that every year more than 3 million children are affected by TBI globally. Incidence rates vary between countries, with the lowest rates in northern European countries (Sweden 12 per 100 000) and highest rates reported from Australia (280 per 100 000). The term TBI encompasses a broad range of injuries to the skull and underlying brain resulting from external forces applied to the head[1,2]. In the paediatric population in Sub-Saharan African countries, death and disability from TBI is still superseded by infectious disease[3]. Mechanisms of injury differ by region and are impacted by socio-economic factors but in general falls, road traffic collisions (RTC), being “struck by/against objects” and assault/NAI (non-accidental injury) are responsible for the majority of injuries[1,4-8]. Severe TBI can result in long-term disability, placing a significant burden on families, caregivers and the health-care system[5,6]. Children have the added impact of long-term sequelae from injuring the developing brain, with recent recognition that even mild TBI can cause persistent neurocognitive and behavioural alterations[9-11] .

1.2 Objectives

Epidemiologic studies investigating injury patterns, risk factors, and resource use for paediatric TBI have been conducted throughout the world[3,5,12,13]. In South Africa, where a high rate of traumatic injury is well documented, children have received little attention as compared to their adult counterparts[14.15]. There have only been a few South African hospital-based studies examining paediatric TBI, hence the motivation for this study[4,14,16].

Chris Hani Baragwanath Academic Hospital (CHBAH) is a tertiary-level institution serving an area of 200km^2 inhabited by 1.7 million people, of which 25.7% are children under 14 years of age[17]. The department of paediatric surgery at CHBAH addresses the general surgical needs of all children admitted up to 10 years of age. This age cut-off was arbitrarily set in the 1990s due to staffing and resource constraints (personal communication, Prof K Lakhoo). Paediatric trauma admissions are a daily occurrence at CHBAH yet there are no formal statistics about these

patients. This 5-year retrospective review of prospectively accumulated data sought to address this gap. It is hoped that the resulting information will aid in guiding primary prevention strategies in our region, and to allow for better resource allocation within our institution.

CHAPTER 2 METHODS

On arrival to CHBAH, all injured patients presenting to the trauma emergency department are assessed, resuscitated as per advanced trauma life support (ATLS) principles and stabilized. They are further cared for by the paediatric surgery service, with the exception of severe isolated head injuries requiring neurosurgical intervention.

2.1 Study Population

All children under 10 years of age admitted to CHBAH with a diagnosis of acute TBI between September 2013 and August 2018 within 24 hours of injury were included in the study. Patients with underlying medical conditions such as febrile seizures or meningitis who were erroneously admitted as TBI were excluded from the study.

2.2 Data collection

Demographic information, mechanism of injury, severity of injury based on Glasgow Coma Scale (GCS), and requirement for computed tomography (CT) brain (and results) were collected for each patient. Outcomes were reported as discharge, transfer to another department or death. Outcomes for children sustaining isolated TBI were compared to those sustaining polytrauma in addition to TBI.

Patients were assigned to one of the following major categories of injury: RTC (including where child is injured pedestrian, passenger inside the vehicle, and falling from a moving vehicle), falls (including falls from height with distance fallen greater than 1.5m, and falling off furniture), being “struck by/against objects”, non-accidental injuries (NAI), penetrating injuries, other and unknown. The category of “unknown” mechanism represented patients with unwitnessed mechanism of injury. The category of “other” included injuries sustained from a school stampede, and other infrequent mechanisms.

Patients were assigned to one of three TBI severity categories based on ATLS principles as mild (GCS 13-15), moderate (GCS 9-12) or severely (GCS 3-8) head injured. For data analysis, files were categorized by age-group as follows: infants (0-12 months), toddlers (1 to 3 years), pre-schoolers (4-6 years), and school-going children (7 to 10 years). A CT brain scan was considered abnormal if acute intracranial or calvarial pathology was identified. Soft tissue changes or incidental findings not related to trauma were not considered significant.

2.3 Statistical analysis

All data were loaded onto an Excel spreadsheet (Microsoft Corporation) and analysed using Stata (StataCorp. 2014 LP, Texas USA) software. Categorical variables were described with frequency, percentages and 95% confidence intervals (CI) where necessary. Continuous variables were described using median and interquartile ranges. Where appropriate statistical significance was accepted as relevant if $p<0.05$.

2.4 Ethical approval

Ethical approval was obtained from the University of Witwatersrand, Human Research Ethics Committee, number M160507.

CHAPTER 3 RESULTS

During the study period 2286 children under the age of 10 years were admitted with a diagnosis of TBI. Eighty-five files contained insufficient data, 34 patients presented more than 24 hours after the occurrence of the injury and 14 patients were misdiagnosed. Hence, 133 patients were excluded from the study, with a final total study population of 2 153 patients.

The mean (SD) age of the study sample was 4.6 (2.7) years. Infants accounted for 12.1% (95% CI 10.7-13.5%) of admissions, toddlers made up 31.5% (95% CI 29.5%-33.5%) of admissions, pre-schoolers contributed 33.6% (95% CI 31.6%-35.6%), and 22.8% (95% CI 21.0%-24.6%) of children were aged 7 to 10 years old. Overall, more than half the admissions, 55% (95% CI 47.0%-51.3%), were children under 5 years. Male gender contributed to 63% (1 350/2 153) of the cohort. For the infant age-group, male to female ratio was 1.3:1 climbing to 2.2:1 for the oldest age-group, averaging to an overall male to female ratio of 1.7:1 (Table 1).

Table 3.1: Summary of demographics and outcomes by cause of injury

Cause	*n* (%)	M:F ratio	Age median (IQR), years	Admission median (IQR), days	Isolated HI *n* (%)	Mortalities *n* (%)
RTC	1 268	1.6:1	5.4 (3.4 – 7.3)	1 (1 – 3)	799 (63%)	36 (2.8%)
Pedestrians	1 015 (80%)	1.7:1	5.6 (3.6 – 7.3)	1 (1 – 3)	634 (62%)	31(3.1%)
Passengers	221(17.5%)	1:1	4.6 (2.5 – 6.6)	2 (1 – 5)	135 (61%)	5 (2.3%)
Fall from vehicle	32 (2.5%)	1.9:1	6.9 (5.8 – 8.2)	1 (1 – 2)	30 (94%)	0
Falls	521	1.7:1	2.3 (0.9 – 5)	1 (1 – 2)	490 (94%)	1 (0.2%)
While playing	321 (61%)	1.8:1	3.3 (1.3 – 5.5)	1 (1 – 1)	305 (95%)	1 (0.3%)
Off furniture	139 (27%)	1.3:1	0.9 (0.6 – 1.6)	1 (1 – 2)	133 (96%)	0
Fall from height	61 (12%)	2.8:1	4.8 (2 – 6.6)	1.5 (1 – 2)	50 (82%)	0
NAI	128	2:1	2 (0.5 – 5.5)	2 (1 – 6)	102 (80%)	5 (3.9%)
Assault	87 (68%)	2.7:1	4.3 (1.1 – 6.5)	3 (2 – 8)	63 (72%)	5 (5.7%)
Dropped	41 (32%)	1:1	0.5 (0.2 – 1.3)	1 (1 – 2)	39 (95%)	0
Struck by/against objects	116	1.9:1	3.9 (2.3 – 65.5)	1 (1 - 2)	91 (79%)	3 (2.6%)
Indoor injuries	20 (17%)	2.3:1	2.9 (1.9 – 4.3)	1 (1 – 2)	15 (75%)	0
Outdoor fixtures	17 (15%)	1.8:1	4.3 (3.2 – 6.8)	1 (1 – 2)	15 (88%)	0
Perimeter gates	79 (68%)	1.8:1	4.3 (2.3 – 6)	1 (1 – 2)	62 (78%)	3 (4.9%)
Penetrating Injuries	10 (0.5%)	2.3:1	2.4 (2.3 – 4.9)	1 (0.25 – 3.75)	4 (40%)	1 (10%)
Other and unknown	110 (5%)	1.9:1	3.5 (1.1 – 6.3)	1 (1 – 2)	95 (86%)	4 (3.6%)
TOTAL:	2 153	1.7:1	4.5 (2.3 – 6.7)	1 (1 – 2)	1 581 (73%)	50 (2.3%)

3.1 Mechanism of injury

RTC was the most frequently reported category of injury with 59% (1 268/2 153) of all injuries sustained (Table 1). Pedestrians incurred 80% (1 015/1 268) of injuries in this category and comprised almost half of the total admissions (47%). Motor vehicle collisions (MVC) in which children were occupants of the vehicle contributed to 17.5% (221/1 268) of RTCs. In addition, 2.5% (32/1 268) of children were injured by falling out of moving vehicles. Falls followed at 24% (521/2 153), as the second most significant category of injury, with infants mostly falling off furniture indoors, and older children falling while playing outdoors (Fig. 1, Fig. 2). Injuries were sustained outdoors for 81% of admissions. Falls from height accounted for 12% (61/521) of this category, mostly as a result of falling from trees, falling off one-storey structures, or from falling off of perimeter walls. Males were strongly represented in this sub-group, with a male to female ratio of 2.8:1.

Within the NAI category, assault accounted for 4% (87/2 153) of the cohort, and males were affected almost 3 times more than females. Infants were the most frequently affected age-group, at 23% (20/87). Forty-one children were reportedly dropped, of which 63% (26/41) were infants. Five children from this sub-category were injured after being thrown in the air, the youngest of these only 1 month of age. Altogether, within the NAI category, infants comprised 36% (46/128) of the cohort. The group of children “struck by/against objects” made up 5.4% (116/2 153) of the cohort. Of these, 17% (20/116) of injuries were caused by indoor items such as television sets, shelving and door-frames falling on children. The rest of these injuries (83%, 96/116) were incurred outdoors, as a result of structural items such as poles, concrete slabs, and perimeter fence entrance gates falling on children. Children aged between 1 and 6 years of age were the most frequently injured here. There were 10 TBI due to penetrating injuries. These included 5 dog bite injuries (one resulting in a death), one stab injury in a 5 year-old, and 4 firearm injuries.

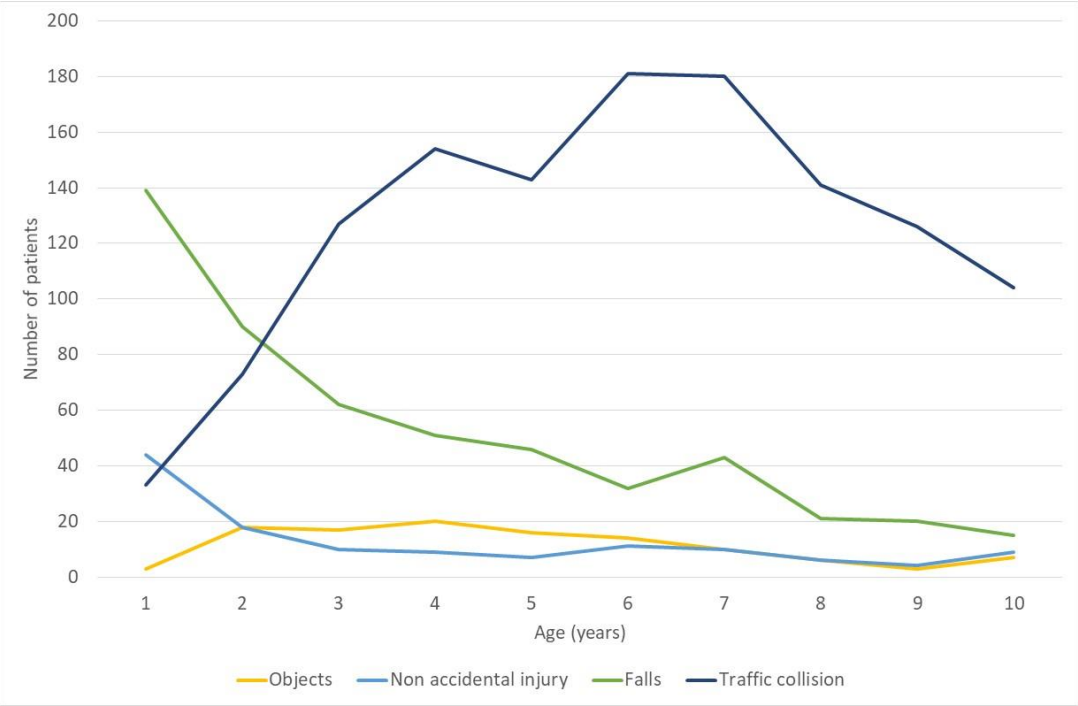

Fig 3.1: Frequency of injury type with increasing age, in years

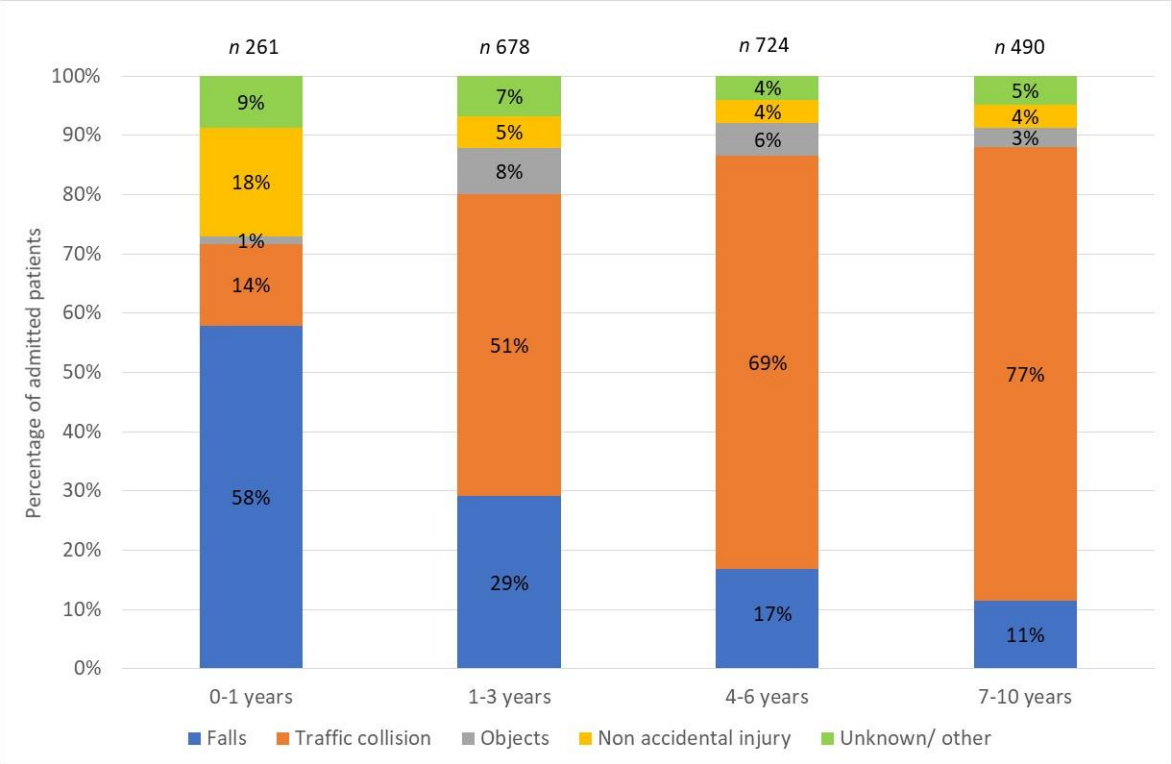

Fig 3.2: Proportion of injury frequency by age-group category

3.2 Injury Severity

Isolated head injuries were sustained by 73% (1 582/2 153) of patients, of which 92% (1 462/1 582) were mild TBI. In contrast, polytrauma patients accounted for 27% (571/2 153) of admissions of which 74% (422/572) were mildly head injured (Table 2). Polytrauma in combination with TBI, although less common, was associated with increased injury severity as compared to isolated TBI (Fig. 3).

Stratifying mortality by injury severity, mild head injuries carried a 0.4% mortality, moderate head injuries a 4% mortality and severe head injuries had the highest mortality of 27% (Table 2). Thus, moving from one severity grade to the next conferred a several-fold increase in mortality. The infant age group demonstrated a statistically significant (p<0.001) increased vulnerability to severe head injuries, with associated mortality of 55% (6/11) compared to 24% (32/131) for the rest of the cohort.

Table 3.2: Effects of Injury Severity on presentation, CT scanning practices and outcomes

Parameter	**Mild HI (GCS 13-15)**	**Moderate HI (GCS 8-12)**	**Severe HI (GCS 3-7)**	**TOTAL**
Total Admissions *n* (%):	1 884 (87%)	127 (6%)	142 (7%)	2 153
0-12 months	245 (94%)	5 (2%)	11 (4%)	261
1-3 years	583 (86%)	48 (7%)	47 (7%)	678
4-6 years	630 (87%)	43 (6%)	51 (7%)	724
7-10 years	426 (87%)	31 (6.3%)	33 (6.7%)	490
Isolated HI *n* (%):	1 462 (78%)	64 (50%)	56 (39%)	1 582
Polytrauma *n* (%):	422 (22%)	63 (50%)	86 (61%)	571
Gender: *n* (%):				
Male	1 170 (87%)	85 (6%)	95 (7%)	1 350
Female	714 (89%)	42 (5%)	47 (6%)	803
M:F ratio	1.6:1	2:1	2:1	1.7:1

Mechanism of Injury: *n* (%):				
RTC	1 059 (83%)	100 (8%)	109 (9%)	1 268
Falls	493 (95%)	13 (2%)	15 (3%)	521
NAI	118 (92%)	3 (2%)	7 (6%)	128
Struck by/against object	104 (90%)	6 (5%)	6 (5%)	116
Penetrating Injuries	6 (60%)	3 (30%)	1 (10%)	10
Other/unknown	104 (94.5%)	2 (1.8%)	4 (3.6%)	110
CT performed *n* (%):	676 (36%)	126 (99%)	132 (93%)	934
0-12months	100 (41%)	5 (100%)	9 (82%) *	114
1-3 years	187 (32%)	47 (97%) †	46 (97%)	280
4-6 years	233 (36%)	43 (100%)	47 (95%) ‡	323
7-10 years	156 (36%)	31 (100%)	30 (91%)	217
Abnormal CT result *n* (%):	278 (41%)	80 (63%)	125 (95%)	483
0-12months	65 (65%) **	3 (60%)	9 (100%)	77
1-3 years	68 (32%) **	26 (56%)	44 (100%)	138
4-6 years	73 (36%) ††	26 (53%) ‡‡	46 (93%)	145
7-10 years	72 (41%) ¶¶	25 (79%)	26 (92%)	123
Mortalities: *n* (%)	7 (0.4%)	5 (4%)	38 (27%)	50
0-12m	1 (0.4%)	0	6 (55%)	7
1-3 years	2 (0.5%)	4 (11%)	12(23%)	18
4-6 years	3 (0.2%)	0	12(26%)	15
7-10 years	1 (0.5%)	1 (2%)	8 (25%)	10
Mortalities: *n* (%)				
Isolated HI	1 (2%)	2 (4%)	12 (24%)	15 (30%)
Polytrauma	6 (12%)	3 (6%)	26 (52%)	35 (70%)
Median (IQR) days admitted	1 (1-3)	5 (2-11)	11 (1-20)	1 (1-3)
Range (days)	0.5-67	0.5-61	0.5-132	0.5-132

* *two children demised prior to imaging;* † *one child demised during resuscitation;* ‡ *four children demised prior to imaging;* ¶ *three children demised prior to imaging*

*Technical problems precluded opening of images and loss of studies: ** three studies lost; †† eleven studies lost; ‡‡one study lost; ¶¶ nine studies lost*

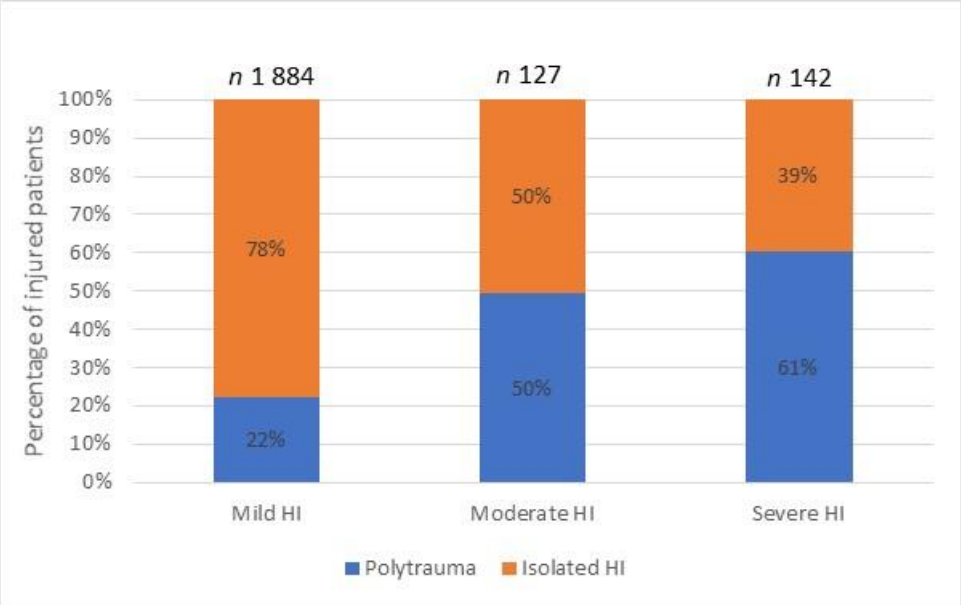

Fig 3.3: Correlation between injury severity and polytrauma versus isolated TBI

3.3 CT-Brain Scanning practices:

CT-brain scans were performed on 933 patients. There were 483 CT scans with reported pathological findings. Of the 261 patients admitted under 1 year old, 44% (114/261) underwent CT-brain scan studies for which 67.5% (77/114) revealed pathology. CT scans for moderate and severe injuries revealed pathology in 79% of cases (Table 2).

3.4 Outcomes:

Eighty six percent (1 861/2 153) of patients were discharged home. Eight percent (176/2 153) were transferred to other specialties including orthopaedics, plastic surgery, and maxillo-facial surgery for further management. Two and a half percent (57/2 153) of patients required continued management with the neurosurgery department, of which 4 demised. Thirteen patients were transferred to neighbouring district hospitals for continued rehabilitation. Duration of admission ranged from less than 24 hours to 132 days. Mean length of stay was 2.4 days with a range of 0.5 to 67 days for isolated head injuries, in contrast to

mean length of stay of 7.2 days with a range of 1 to 132 days for patients admitted due to polytrauma with associated TBI. Overall mortality for the cohort was 2.3% (50/2153). RTC were responsible for 72% (36/50) of mortalities.

All children who sustained non-accidental injuries and those with injuries suggestive of unintentional neglect (infants falling off furniture, children falling out of moving vehicles) were referred on to in-house social workers. All patients with positive CT scan findings (483/2 153) were consulted by the neurosurgery service but only 2.5% required take-over of management. Patients who were admitted for longer than 2 days (571/2153) were additionally assessed by the occupational therapists, physiotherapists and dieticians.

3.5 Temporal injury trends:

Various temporal patterns were noted in this study. Week-end days incurred the most admissions. A decrease in frequency of falls and RTC was noted during the winter months, but increased during summer months and school holiday periods. From the start of the study period in 2013 there was an annual decline in admissions, followed by steady increases after 2016 (Fig. 4).

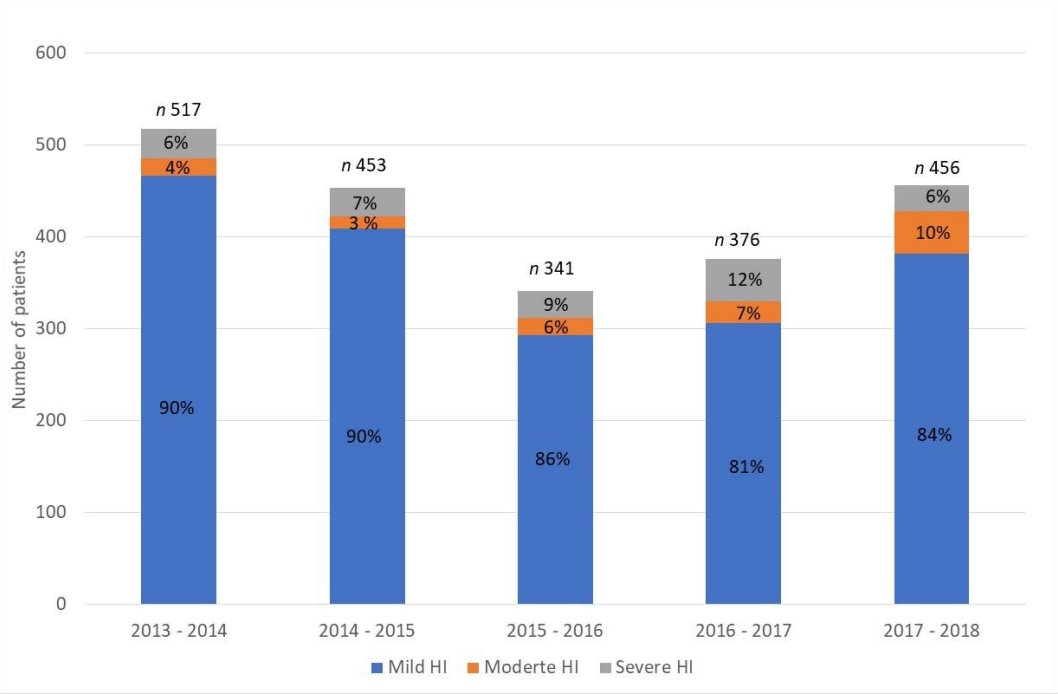

Fig 3.4: Annual incidence of paediatric TBI admissions by severity of injury, September 2013-August 2018

(date of admission not known for 8 patients)

CHAPTER 4 DISCUSSION

Regional epidemiological studies such as this one facilitate the description of injuries peculiar to local environments. In the United Kingdom (UK), results of the Confidential Enquiry performed in 2014 assisted in the revision of the National Institute for Health and Care Excellence (NICE) guidelines for paediatric head injuries[5]. A South African based study from 2007 reported that the major risk factors for TBI included extremes of age, male gender and low socioeconomic status[7]. The implication that young children from impoverished environments are more vulnerable to trauma was paralleled in our findings, as well as studies from abroad[18].

Buitendag *et al* summarized 7 studies between 1984 and 2014 pertaining to paediatric TBI in South Africa and compared these to their own data. To date, reports from Red Cross War Memorial Children's Hospital and Pietermaritzburg Hospital account for the bulk of published studies[4,14,15]. Publications that focus on TBI in the adult population of Gauteng exist but the paediatric TBI population of Soweto has not been comprehensively described[7,8,19].

In this cohort males incurred injuries more frequently than females. This gender disparity is documented almost ubiquitously both locally and internationally[1,5,6,20]. For falls from height, males were also more prevalent, with a male to female ratio of 2.8:1, perhaps reflecting increased risk-taking behaviour of boys[21].

Similar to other low and middle income countries, pedestrian vehicle collisions were the dominant cause for admissions, contrasting with higher income countries where falls occurred with greater frequency[1,18,22]. Injuries reported in this study occurred most frequently outdoors, contrary to many other studies reporting injuries occurring more frequently in the home or whilst at school[1,4,5,23]. This may be a reflection of the socioeconomics of the region: children play outdoors in the absence of suitable supervised recreational areas, walk (sometimes long distances) to school without adult supervision, and are often left home alone while caregivers are at work.

There is mounting evidence that behavioural factors predispose children to pedestrian traffic collisions. The cognitive process of interpreting traffic cues and having adequate psychomotor skills to act appropriately may not be sufficiently developed in children under 10 years of age. A significant number of RTC are reportedly due to acts of 'darting out' into streets or 'dashing across intersections' [24] This impulsive decision-making may predispose younger children to the higher

incidence of pedestrian traffic collisions, as noted in this study. This brings into question the efficacy of child-directed education in this age-group and motivates for added awareness programs involving driver-behaviour. Infrastructure modification such as traffic calming structures in high-risk areas including near schools and residential areas may offer some reprieve.

In keeping with other low and middle income countries, injuries due to precarious household infrastructure were common[7,25]. NAI presents a serious concern as this category carried a 4% mortality (double that of the entire cohort). Children under a year of age were most frequently affected by NAI, a finding paralleled in other studies[5,6,26].

The need to identify a clinically important injury in mild TBI patients must be balanced against the risk of unnecessary exposure to ionizing radiation from performing CT brain scans[27,28]. Internationally, various algorithms have been developed to help address this[29]. We reported a CT brain scanning rate of 36% for mild TBI of which 41% identified pathology. Due to resource constraints in our institution children were frequently admitted for observation and escalated to performing a CT scan if the need arose. These are conservative figures compared to higher income countries[30,31] however for this cohort, this strategy did not incur adverse outcomes.

The decrease in TBI admissions in 2015-2016 may have occurred for several reasons. The most recent regional population census reported a decrease in population numbers and birth rates for the area during that period[17]. Simultaneously, a primary level hospital was opened in Soweto in 2014, diverting minor injuries from CHBAH. The steady increase in TBI admissions which followed from 2016 may reflect a broader cyclic population pattern in the region, a recovering population growth or the possibility that the new primary level institution had become saturated. An increase in RTC was noted in the summer months and over periods of school holidays. As with other reports, week-end periods incurred higher admission rates. With the exception of NAI which was consistently reported throughout the year, the temporal pattern in paediatric TBI noted here mirrors previously reported seasonal variability in injury patterns in Soweto[32].

Children under a year of age are completely dependent on their caregivers. They in turn, may not adapt their level of supervision to the child’s evolving motor

development timeously. This renders infants vulnerable to falls from surfaces (furniture) that they are placed on. They are more frequently dropped by caregivers and siblings and carry a higher risk for NAI. Infants with mild TBI incur higher rates of CT positive pathology, and their risk of mortality in severe TBI is significantly increased as compared to older children. This has identified an opportunity to target educational programs aimed at mothers attending antenatal clinics and caregivers at well-baby clinics.

It is widely accepted that mild TBI can result in long-term neurocognitive sequelae[10,11,33]. To assess this in the CHBAH catchment area, we undertook a collaborative prospective study to assess neurocognitive abilities of mildly head-injured children compared to age-matched uninjured children from the same community. Together with the University of the Witwatersrand psychology department and in association with Oxford University the THINK trial (Traumatic Head Injury: Neurocognitive assessment in Kids) was initiated, based on the population represented in this cohort. Preliminary reports suggest that elements such as speed of processing abilities may be affected following mild TBI, which can have a knock-on effect with regards to future cognitive development and scholastic capabilities, creating further difficulties in the lives of already marginalised children.

CHAPTER 5 CONCLUSIONS

Paediatric TBI was demonstrated to be a resource intensive public health concern. The increased vulnerability of infants to TBI was identified and the prevalence of RTC was highlighted as a necessary target for primary prevention. Antenatal clinics, schools and local clinics could be considered as points of contact for this purpose. Further research into possible primary prevention solutions specific to Soweto is needed. We hope that the results from the THINK study will identify modifiable targets for early rehabilitation to curb long-term sequelae of mild TBI.

5.1 Limitations of the study:

The study was a retrospective analysis of information contained in a database and supplemented by case files. Because of language barriers and young age of children, mechanism of injury could not be identified for 85 patients resulting in some attrition of data. The study invariably excludes children who demised on scene due to their injuries and patients who may have been seen by feeder hospitals and clinics and managed there. The cut-off admission age was 10 years old, which is not representative of the paediatric population, thus, it is difficult to make comparisons with findings from other national centres.

5.2 Addendum to limitations:

Resource limitations with data collection and processing made certain objectives impossible to attain in the timeframe for which this project was given. This included reflection on the true extent of multidisciplinary involvement and financial burden (in monetary terms) of TBI in this cohort. This was only realised after objectives were proposed.

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MMed Research Protocol

An Audit of Blunt Head Injuries Sustained by Children up to 10 years of Age Admitted to Chris Hani Baragwanath Academic Hospital

Principal Investigator: Dr Vered Lack

Supervisors: Professor J Loveland

Dr P Fonteh

TITLE: An Audit of Blunt Head Injuries Sustained by Children up to 10 years of Age Admitted to Chris Hani Baragwanath Academic Hospital

1. INTRODUCTION

Chris Hani Baragwanath Academic Hospital (CHBAH) is a large tertiary level hospital in the heart of Soweto. It serves a vast community and is a referral center for hospitals even further afield. It is staffed by a bustling community of health workers, ranging from trainee to sub-specialists. It is resource restrained, but despite this, is able to maintain a high standard of care. To date, a thorough investigation with respect to the prevalence, aetiology, severity, and initial management of blunt head injuries sustained by children admitted to CHBAH has not been undertaken. Such an endeavour would inform care-givers on the adequacy of the level of care in the first 24 hours that they are offering, and managers would be alerted to improvements that could be facilitated, to the overall betterment of care to the patients.

1.1 Appraisal of the literature:

Paediatric Traumatic Brain Injury (TBI) has been referred by some authors as a "silent epidemic" due to its insidious long term affects, and as "a neglected disease of modern society" on account of the lack of information available to quantify and expose this disease[1,2]. In developed countries where infection and malnutrition rates have declined, disability and death due to trauma have increased substantially. Approximately 1/3 of deaths in children aged 1-14 are now caused by trauma, and traumatic head injury is the leading cause of non-fatal injury in children[1]. This is demonstrated consistently in developed countries such as Korea, Australia, the United Kingdom and the United States[1,3,4]. Crowe et al noted that there is little documented about blunt head injuries in children under 3, despite the high frequency

with which this injury is encountered in this age group (and the potential long term disability), and undertook a study to better understand the epidemiology and outcomes[5].

African studies confirm that although communicable diseases are still the most significant cause of childhood mortality on the continent, trauma (with traumatic head injuries being most frequent) are gaining significance with regards to morbidity[3,6].

It has been proposed that in South Africa the main causes of traumatic brain injury (TBI) in children can be attributed to high rates of violence and high rates of MVAs. In addition, Levin suggests that due to socio-economic and socio-cultural influences, management of TBI differs from approaches adopted in developed countries. This paper also suggests that children may sustain TBI as a result of adult-to-adult violence. Anecdotal observations propose that at least the initial management of TBI (as with other trauma) at CHBAH is managed in accordance with best practices internationally and that the only limiting factor (as faced by all developing countries) may be that of resource shortages. It is also noted that there are no dedicated paediatric rehabilitation units for children with TBI, with no state-run facilities offering an after-discharge service[7]. A retrospective study looking at severe traumatic brain injuries at Red Cross War Memorial Children's Hospital similarly found that MVAs constitute the majority of injuries, but also noted that injury etiology could also be stratified by age group. This study group also found significance in a patient's socioeconomic status with regards to level of care and subsequent prognosis. They too saw the relevance and need for information regarding TBI admissions, etiologies and outcomes. According to the authors, such information would eventually serve as

a guide for prevention strategies, highlight (and thus target) high-risk groups and form part of awareness-building campaigns[2].

Head injuries in children are responsible for many emergency department visits, and this is a world-wide phenomenon. For the most part, these are minor injuries not requiring admission. Over the years, many clinicians have proposed clinical decision rules to aid in identifying (with consistency) significant intracranial injury in order to prevent neuro-disability and even death. Thus, evidence-based head injury clinical decision making rules have been derived to aid physicians in identifying patients at risk of having clinically significant intracranial injuries, with some countries choosing to modify protocols to better suit their local conditions. Examples of such protocols include CATCH: the Canadian Assessment of Tomography for Childhood Head Injury, PECARN (Pediatric Emergency Care Applied Research Network): a group from the USA who developed a prediction rule for the identification of children at very low risk of clinically important traumatic brain injury, and CHALICE: the Children's Head Injury Algorithm for the Prediction of Important Clinical Events (from the United Kingdom). In turn, various study groups have applied these to various local scenarios to ascertain their ubiquity in environments outside of where they were created. Such protocols have also been challenged against each other in the same environment to establish which is the superior algorithm[8,9].

In the UK, National clinical Guidelines are published, commissioned by NICE (the National Institute for Health and Care Excellence) and are used as the standard from which level of care is measured. A Head Injury Guideline exists, updated in 2014, which makes recommendations on management (based on available evidence) on

the triage, assessment, investigation and early management of head injuries (protocols available for adults and children). Prior to the inception of NICE head injury guidelines, the UK was using level of consciousness and skull X-ray and neurological observations as primary assessment tools, with computed tomography (CT) scans reserved for more severely injured patients[10].

The first UK-wide guidelines on identifying patients who were at high risk of intracranial complications following a head injury were drawn up by a working party of Neurosurgeons in 1984. At that time the main investigation was the skull X-ray. CT scan use was advocated by Neurosurgeons in 1990, with superior specificity and sensitivity to X-rays, and with improved technology (reduced time of investigation, improved image output, reduction of radiation exposure) skull X-ray use is falling away. In comparison to the NICE guidelines, North American Guidelines have a lower threshold for CT scanning, with between 75 and 100% of all patients with normal Glasgow Coma Scale (GCS) and documented loss of consciousness being scanned. Where the UK guidelines are increasing the use of CT scanning in their recommendations (partly due to improved access, and clinical evidence), the US guidelines seek to decrease the frequency of use of CT scanning. National guidelines and protocols are attractive as they allow consistent management across centers, so that clinicians of varying levels of training are able to offer a similar service and are able to consistently refer to higher level centers when appropriate[10].

Since the introduction of computed tomography in the 1970s its use has become indispensable in the management of trauma patients, and in particular, the diagnostic reference standard for managing acute head injuries[11]. Computed Tomography in the

acute setting has revolutionized the management of traumatic injuries, and this investigation is integral to many a trauma center. Despite its many benefits, there are also several disadvantages to administering this investigation. In children in particular, CT scanning may necessitate the use of sedation, restraint, added stress and increased exposure to ionizing radiation. Several studies have confirmed that there is a small but significant increase in the rate of cancer as a consequence to these exposures[12,13,14]. Hence, it has been suggested that CT scanning of children should be justified by severity of the injury. However, it has been noted that there are children who present with seemingly innocuous head injuries but have clinically significant intracranial injury leading to death or severe disability[15,16]. Over recent years it has become apparent that a balance needs to be sought between blanket scanning of all injured children (and increasing their risk for malignancy), and between following more conservative management paths and risking missing clinically significant and reversible injuries, with dire consequences[17].

2. STUDY AIM:

Therefore, the aim of the study is to expose the causes, and the prevalence of traumatic brain injuries in children under 10 years of age presenting to CHBAH and to assess adequacy of initial acute care. It is hypothesized that these will stratify by age, mechanism of injury and severity, ie: that certain injuries will be more prevalent in certain age groups. It is also hypothesized that the majority of injuries will comprise mild injuries receiving adequate care. More severe injuries

requiring intensive acute care may experience a disparity in care, due to lack of resources.

3. STUDY OBJECTIVES:

This study serves as an audit of the state of affairs regarding blunt head injuries in children under the age of 10 years presenting to CHBAH.

The objectives of this audit are several-fold:

- To quantify the burden of this disease in terms of: demographics, causes and severity
- To explore the multidisciplinary involvement in its management and thus the resource burden on CHBAH
- To compare initial management as undertaken at CHBAH with current best practices.

4. METHODS:

a. Design: This is a retrospective, cross sectional study aimed at answering the questions set out in the study objectives listed above.

b. Site of Study: Chris Hani Baragwanath Academic Hospital.

c. Study Population: All children from birth to 10 years of age who presented to the Department of Paediatric Surgery for admission as a result traumatic blunt head injury (from all causes), that occurred from 1 September 2013 to 28 February 2015.

d. Sampling:

Sample Size: As this is the first such study on this population, all admissions for TBI will be included in order to obtain an accurate picture of the present situation. This number will be compared to the overall total of paediatric trauma admissions presenting to CHBAH. It is hypothesized that the study will comprise of approximately 600 cases of TBI from a total of around 800 trauma admissions.

Inclusion and exclusion criteria: Data from all children admitted for the prescribed time period with a diagnosis of TBI or multiple injuries, including TBI will be collected. Occasionally, when it is uncertain whether a child fell secondary to a seizure (due to epilepsy or infection) or vice versa, the current protocol is for traumatic injury to be excluded first. Thus, some admitted patients may have medical conditions, and not TBI. Where this is the case, patients will be excluded from the study. Other exclusions will include patients who are admitted for social reasons (late night, lack of transport or family member to collect child) and may be admitted under the guise of 'Neurological Observations'. This is always documented in the bed-letter. Lastly, where incomplete documentation causes data collection to be insufficient, that file will be excluded from the study. Furthermore, patients referred from other hospital facilities and patients presenting after 24 hours of injury will also be excluded as these patients will fall outside the scope of initial acute care, as provided by the facilities of CHBAH.

e. **Measuring Instrument:** Data will be collected using a Data Sheet, focusing on the following parameters-

    i. Demographics: gender, age (in months) at injury

ii. Pre-hospital: mechanism of injury, whether incident was witnessed by primary care-giver, mode of transport to hospital, initial pre-hospital management, initial GCS, initial symptoms

iii. At presentation to Trauma casualty: GCS, need for active resuscitation, comorbidities

iv. Imaging: CT scanning, results of scan

v. Allied professions: need for Neurosurgical consultation and/or intervention, other disciplines involved, social worker involvement

vi. Hospital care: ICU admission, days hospitalized, need for rehabilitation, outcome with regards to discharge or mortality.

Data Collection: Information will be collated from the following sources: Department of Paediatric surgery database, Patient records, admission records and ICU records (for patients admitted to the ICU). Documents will be scrutinized for the above-mentioned parameters, and documented on an anonymous datasheet. The data sheet will only be identified by a study number, which will be cross referenced (in a physically separate location) to the file number. Hence, data sheets will respect patient anonymity. Aside from age and duration of hospitalization, parameters collected will be categorical. All data will be collected by myself.

f. Pilot Study: Not necessary for this study

g. Sources of Bias: Due to the rotational nature of the Department of Surgery, doctors with different levels of familiarity to children will have been involved in documenting information in files and the Data Base of the department. Children may respond differently to the trauma of the injury, strange hospital environment and unknown medical staff. This may influence the attending clinician's perception of severity of injury. To exclude this bias, only objective data such as

GCS, evidence of vomiting, seizures, documented injuries etc will be collected. Where GCS might be overestimated due to time of presentation (early hours of morning when children are normally asleep, and therefore may appear drowsy) the best score will be recorded. If GCS is not 15/15 at time of presentation, this is monitored and any improvement/deterioration is documented as part of neurological observations in patient files.

5. DATA ANALYSIS:

Data collected on Data Sheets will be captured onto a Microsoft Excel spreadsheet, cleaned and coded. The data are mainly categorical and will be presented as percentages and frequencies, looking at relationships using the Chi Squared test. All analysis will be performed at the 95% confidence interval (CI). Data will be analysed using the latest version of STATA (Stat Corp), with the assistance of statisticians at Philip Tobias Building. Patients will be quantified by age group, and gender and this will be compared to prevalence of injury type. Severity of head injury will be classified as mild, moderate or severe according to allocated GCS score (mild: 13-15, moderate: 12-9, severe: 3-8). Adequacy (and frequency) of CT scan testing (in terms of appropriateness of performance) will be assessed by quantifying total CT Brain tests performed and correlating this number by comparing numbers of: negative tests vs positive tests. And where tests are positive, these will be reported as skull injuries (such as fractures), intracranial pathologies, and both.

Use of allied medical disciplines as well as the use of other hospital resources will be critically appraised, by assessing frequency of use relative to number of admissions.

ETHICAL CONSIDERATIONS:

- Permission will be obtained from the management of CHBAH to access records

- All data will be kept anonymous, in a locked cupboard and password protected
- Permission will be obtained from the HOD of the Department of Paediatric Surgery to access patient data from department data base
- Permission to conduct the study to be obtained from Wits University Postgraduate Committee
- The study will be subject to approval of the Human Research Ethics Committee

6. TIMING:

PROCESS	J	F	M	A	M	J	J	A	S	O	N	D
Literature Review	**X**	**X**										
Protocol Preparation	**X**	**X**										
Protocol Assessment			**16/03**									
Ethics Application				**31/03**								
Data Collection					**x**	**X**	**x**	**x**				
Data Analysis									**x**	**x**		
Write Up											**x**	**x**

Completion of study anticipated approximately a year after Protocol and Ethics approval.

7. FUNDING:

Self funded

8. PROBLEMS:

Due to the paper based nature of record-keeping at CHBAH, some attrition of data is anticipated.

9. ANNEXURES:

- Letter from CEO of CHBAH giving permission to access patient records
- Letter from HOD of Paediatric Surgery Department allowing access to Database
- Data Collection Sheet

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APPENDIX 2: Datasheet

DATA SHEET

PATIENT INFORMATION								
RESEARCH NUMBER								
DATE OF ADMISSION	**__ __ / __ __ / 20 __ __**				**DATE OF DISCHARGE**	**__ __ / __ __ / 20 __ __**		
AGE:								
					GENDER	**MALE**	**FEMALE**	

CLINICAL INFORMATION												
MECH OF INJURY	**PENETRATING**					**GUNSHOT**		**STAB**		**OTHER**		
	BLUNT					**MVA**	**PVA**	**FALL**	**ASSUALT**	**NAI**		
	INITIAL GCS					**___/15**						
	LOC	**Y**	**N**			**DURATION**						
	SEIZURE	**Y**	**N**			**VOMITING**			**N**	**Y**		
	AMNESIA	**Y**	**N**			**0**			**<3**	**>3**		
	SCALP HAEMATOMA NOTED		**Y**	**N**								
	INCIDENT WITNESSED	**Y**	**N**			**BY WHO**						
TRANSPORT	**PRIVATE**					**EMS**						
IF EMS	**INTUBATION**	**Y**	**N**	**IF YES**		**COMPICATED**		**UNCOMPLICATED**				
IF COMPLICATED - SPECIFY												
RESUS(TIME OF ARRIVAL TO RESUS)												
INTUBATED ON ARRIVAL	**YES**					**NO**						
	GCS											
RX	**INTUBATION**		**Y**	**N**		**VENTALATION**		**Y**	**N**			
	CVP		**Y**	**N**								
INITIAL REPORT & WORKING DX												
CT BRAIN (TIME PERFORMED)	**NAD**	**SAH**	**SDH**	**ICB BLEED/CONTUSION**		**RAISED ICP/DAI**	**#BOS**					
REVIEWED REPORT												
CT BRAIN	**NAD**	**SAH**	**SDH**	**ICD BLEED / CONTUSION**		**RAISED ICP/DAI**	**#BOS**					
FRACTURE	**SIMPLE LINEAR**			**DEPRESSED**			**COMPLEX**					
NEURO SURGERY CONSULT	**YES**				**NO**							
IF YES	**VERBAL**				**PHYSICAL CONSULT**							
OUTCOME												
SOCIAL WORKER CONSULT	**YES**				**NO**							
IF YES: RECOMMENDATION												
ALLIED MEDICAL PROFESSIONS CONSULTED (SPECIFY)												
SX INTERVENTION	**Y**	**N**	**IF YES SPECIFY**									
ICU ADMISSION	**Y**	**N**	**IF YES**	**ICP MONITORING**		**DEFINITIVE SURGERY**						
FOLLOW UP	**6 WEEKS**				**12 WEEKS**							

APPENDIX 3: Ethics Clearance Certificate

R14/49 Dr Vered Lack et al

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M160507

NAME: (Principal Investigator)	Dr Vered Lack et al
DEPARTMENT:	General Surgery Chris Hani Baragwanath Academic Hospital
PROJECT TITLE:	An Audit of Blunt Head Injuries Sustained by Children up to 10 Years of Age Admitted to Chris Hani Baragwanath Academic Hospital
DATE CONSIDERED:	27/05/2016
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Prof Jerome Loveland
APPROVED BY:	Professor P. Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	13/06/2016

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 10004,10th floor, Senate House/2nd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand. I/We fully understand the the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated,from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. in this case, the study was initially review in May and will therefore be due in the month of May each year.

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX 4: Turnitin Report

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ORIGINALITY REPORT

5%	3%	3%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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★ S Cawood, S Naidoo, G Okudo, S Velaphi, C Verwey. "Outcomes of paediatric patients ventilated in a high-care area outside an intensive care unit", South African Medical Journal, 2020

Publication

Exclude quotes	On	Exclude matches	< 5 words
Exclude bibliography	On		

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SAMJ RESEARCH

The epidemiology of traumatic brain injuries sustained by children under 10 years of age presenting to a tertiary hospital in Soweto, South Africa

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Background. Traumatic brain injury (TBI) in the paediatric population is a significant contributor to death and disability worldwide. In sub-Saharan Africa, death and disability from TBI are still superseded by infectious disease. Mechanisms of injury differ by region and socioeconomics, but in general, falls, road traffic collisions (RTCs), being 'struck by/against objects' and non-accidental injuries (NAIs) are responsible for most cases.

Objectives. To: (*i*) quantify the burden of TBI in terms of demographics, causes and severity; (*ii*) explore resource utilisation regarding length of stay, computed tomography (CT) brain scan use and multidisciplinary participation; (*iii*) interrogate possible temporal patterns of injury; and (*iv*) thus identify potential targets for community-based prevention strategies.

Methods. In a 5-year retrospective review of all children aged <10 years admitted with TBI between September 2013 and August 2018, demographics, date of injury, mechanism of injury, severity of TBI based on the Glasgow Coma Scale, and requirement for a CT brain scan were collected for each patient. Outcomes were reported as discharge, transfer or death. Outcomes for children sustaining isolated TBI were compared with those for children sustaining TBI with polytrauma.

Results. A total of 2 153 patients were included, with a mean (standard deviation) age of 4.6 (2.7) years and a male/female ratio of 1.7:1. RTCs were the most frequent cause of injury at 59% (80% of these were pedestrian-vehicle collisions), followed by falls at 24%. Mild TBIs accounted for 87% of admissions, moderate injuries for 6%, and severe injuries for 7%. Polytrauma was associated with increased severity of TBI. The cohort had a 2.3% mortality. NAIs accounted for 6% of injuries and carried a 4% mortality. The median (interquartile range) duration of hospitalisation was 1 (1 - 3) days, ranging from <24 hours to 132 days. CT scans were performed on 43% of admitted patients, and 48% of patients had consultations with another medical or allied medical discipline. Injuries were more frequent during the summer months and over weekends. Infants aged <1 year were identified as a group particularly vulnerable to injury, specifically NAI.

Conclusions. Paediatric TBI was demonstrated to be a resource-intensive public health concern. From the results, we identified potential primary prevention targets that could perhaps be incorporated into broader community-based intervention programmes. We also identified a need to study long-term consequences of mild TBI further in our paediatric population.

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Traumatic brain injury (TBI) in the paediatric population is a significant contributor to death and disability worldwide. It is estimated that every year >3 million children are affected by TBI globally. Incidence rates vary between countries, with the lowest rates in northern European countries (Sweden 12 per 100 000) and the highest rate reported from Australia (280 per 100 000). The term TBI encompasses a broad range of injuries to the skull and underlying brain resulting from external forces applied to the head.[1,2] In the paediatric population in sub-Saharan African countries, death and disability from TBI are still superseded by infectious disease.[3] Mechanisms of injury differ by region and are affected by socioeconomic factors, but in general, falls, road traffic collisions (RTCs), being 'struck by/against objects' and assault/non-accidental injury (NAI) are responsible for the majority of cases.[3,4,8] Severe TBI can result in long-term disability, placing a significant burden on families, caregivers and the healthcare system.[9,10] Children have the added impact of long-term sequelae from injuring the developing brain, with recent recognition that even mild TBI can cause persistent neurocognitive and behavioural alterations.[9-12]

Epidemiological studies investigating injury patterns, risk factors and resource use for paediatric TBI have been conducted throughout the world.[2,3,12,13] In South Africa (SA), where a high rate of traumatic injury is well documented, children have received little attention compared with their adult counterparts.[14,15] There have only been a few SA hospital-based studies examining paediatric TBI, hence the motivation for the present study.[4,14,16]

Chris Hani Baragwanath Academic Hospital (CHBAH) in Soweto, Gauteng Province, is a tertiary-level institution serving an area of 200 km^2 inhabited by 1.7 million people, of whom 25.7% are children aged <14 years.[17] The Department of Paediatric Surgery at CHBAH addresses the general surgical needs of all children admitted up to 10 years of age. This age cut-off was arbitrarily set in the 1990s owing to staffing and resource constraints (Prof. K Lakhoo, personal communication, 8 October 2020). Paediatric trauma admissions are

a daily occurrence at CHBAH, yet there are no formal statistics on these patients.

Objectives

This 5-year retrospective review of prospectively accumulated data sought to address this gap. It is hoped that the resulting information will aid in guiding primary prevention strategies in our region, and allow for better resource allocation in our institution.

Methods

On arrival at CHBAH, all injured paediatric patients presenting to the trauma emergency department are assessed, resuscitated as per advanced trauma life support (ATLS) principles, and stabilised. They are further cared for by the paediatric surgery service, with the exception of severe isolated head injuries requiring neurosurgical intervention.

Study population

All children aged <10 years admitted to CHBAH with a diagnosis of acute TBI between September 2013 and August 2018 within 24 hours of injury were included in the study. Patients with underlying medical conditions such as febrile seizures or meningitis who were erroneously admitted as TBI were excluded from the study.

Data collection

Demographic information, mechanism of injury, severity of injury based on the Glasgow Coma Scale (GCS), and requirement for a computed tomography (CT) brain scan (and results) were collected for each patient. Outcomes were reported as discharge, transfer to another department or death. Outcomes for children sustaining isolated TBI were compared with those for children sustaining polytrauma in addition to TBI.

Patients were assigned to one of the following major categories of injury: RTCs (including where the child is injured as a pedestrian or a passenger inside the vehicle, or by falling from a moving vehicle), falls (including falls from a height with distance fallen >1.5 m, and falling off furniture), being 'struck by/against objects', non-accidental injuries (NAIs), penetrating injuries, other and unknown. The category of 'unknown' mechanism represented patients with unwitnessed mechanism of injury. The category of 'other' included injuries sustained from a school stampede, and other infrequent mechanisms.

Patients were assigned to one of three TBI severity categories based on ATLS principles as mild (GCS 13 - 15), moderate (GCS 9 - 12) or severe (GCS 3 - 8) head injury. For data analysis, files were categorised by age group as follows: infants (0 - 12 months), toddlers (1 - 3 years), preschoolers (4 - 6 years), and school-going children (7 - 10 years). A CT brain scan was considered abnormal if acute intracranial or calvarial pathology was identified. Soft-tissue changes or incidental findings not related to trauma were not considered significant.

Statistical analysis

All data were loaded onto an Excel spreadsheet, version 2015 14026.20308 (Microsoft Corp., USA) and analysed using Stata version 15.1 2014 LP (StataCorp, USA) software. Categorical variables were described with frequencies, percentages and 95% confidence intervals (CIs) where necessary. Continuous variables were described using medians and interquartile ranges. Where appropriate, statistical significance was accepted as relevant if $p<0.05$.

Ethical approval

Ethical approval was obtained from the University of the Witwatersrand Human Research Ethics Committee (ref. no. M160507).

Results

During the study period, 2 286 children aged <10 years were admitted with a diagnosis of TBI. Eighty-five files contained insufficient data, 34 patients presented >24 hours after the occurrence of the injury, and 14 patients were misdiagnosed; 133 patients were therefore excluded from the study, with a final total study population of 2 153 patients.

The mean (standard deviation) age of the study sample was 4.6 (2.7) years. Infants accounted for 12.1% (95% CI 10.7 - 13.5) of admissions, toddlers for 31.5% (95% CI 29.5 - 33.5), preschoolers for 33.6% (95% CI 31.6 - 35.6), and children aged 7 - 10 years for 22.8% (95% CI 21.0 - 24.6). Overall, more than half the children admitted (55%; 95% CI 47.0 - 51.3) were aged <5 years. Males made up 63% (n=1 350/2 153) of the cohort. In the infant age group, the male/female ratio was 1.3:1, climbing to 2.2:1 for the oldest age group. The overall male/female ratio was 1.7:1 (Table 1).

Mechanism of injury

RTCs were the most frequently reported category of injury, accounting for 59% (n=1 268/2 153) of all injuries sustained (Table 1). Pedestrians incurred 80% (n=1 015/1 268) of injuries in this category and comprised almost half of the total admissions (47%). Motor vehicle collisions in which children were occupants of the vehicle contributed to 17.5% (n=221/1 268) of RTCs. In addition, 2.5% of children (n=32/1 268) were injured by falling out of moving vehicles. Falls followed as the second most significant category of injury at 24% (n=521/2 153), with infants mostly falling off furniture indoors and older children falling while playing outdoors (Figs 1 and 2). Injuries were sustained outdoors for 81% of admissions. Falls from a height accounted for 12% (n=61/521) of this category, mostly falling from trees, falling off one-storey structures or falling off perimeter walls. Males were strongly represented in this subgroup, with a male/female ratio of 2.8:1.

In the NAI category, assault accounted for 4% (n=87/2 153) of the cohort, and males were affected almost three times more than females. Infants were the most frequently affected age group, at 23% (n=20/87). Forty-one children were reportedly dropped, of whom 63% (n=26/41) were infants. Five children in this subcategory were injured after being thrown in the air, the youngest of these only 1 month of age. Altogether, in the NAI category, infants comprised 36% (n=46/128) of the cohort. The group of children 'struck by/against objects' made up 5.4% (n=116/2 153) of the cohort. Of these injuries, 17% (n=20/116) were caused by indoor items such as television sets, shelving and door-frames falling on children. The rest of these injuries (83%; n=96/116) were incurred outdoors, as a result of structural items such as poles, concrete slabs and perimeter fence entrance gates falling on children. Children aged between 1 and 6 years of age were the most frequently injured here. There were 10 TBIs due to penetrating injuries. These included 5 dog bite injuries (1 resulting in death), 1 stab injury in a 5-year-old, and 4 firearm injuries.

Injury severity

Isolated head injuries were sustained by 73% (n=1 582/2 153) of patients, of which 92% (n=1 462/1 582) resulted in mild TBI. In contrast, polytrauma patients accounted for 27% (n=571/2 153) of admissions, of whom 74% (n=422/572) had mild TBI (Table 2). Polytrauma in combination with TBI, although less common, was associated with increased injury severity compared with isolated TBI (Fig. 3).

Stratifying mortality by injury severity, mild head injuries carried a 0.4% mortality, moderate head injuries a 4% mortality and severe

Table 1. Summary of demographics and outcomes by cause of traumatic brain injury

Cause	n (%)	M:F ratio	Age (years), median (IQR)	Admission (days), median (IQR)	Isolated HI, n (%)	Mortality, n (%)
RTC	1 260	1.6:1	5.4 (3.6 - 7.2)	1 (1 - 3)	799 (63)	46 (2.6)
Pedestrians	1 003 (80)	1.7:1	5.6 (3.6 - 7.2)	1 (1 - 3)	634 (62)	31 (3.1)
Passengers	221 (17.5)	1:1	6.6 (2.5 - 6.6)	2 (1 - 5)	130 (60)	5 (2.3)
Fall from vehicle	32 (2.5)	1.9:1	6.9 (5.8 - 8.2)	1 (1 - 2)	30 (94)	0
Fall	521	1.7:1	2.3 (0.9 - 5)	1 (1 - 2)	498 (94)	1 (0.2)
While playing	321 (61)	1.8:1	3.3 (1.3 - 5.5)	1 (1 - 2)	305 (95)	1 (0.3)
Off furniture	139 (27)	1.5:1	0.9 (0.6 - 1.6)	1 (1 - 2)	133 (96)	0
Fall from height	61 (12)	2.8:1	6.8 (2 - 9.6)	1.5 (1 - 2)	50 (82)	0
NAI	128	2:1	2 (0.5 - 3.5)	2 (1 - 6)	102 (80)	1 (1.0)
Assault	87 (68)	2.7:1	4.3 (1.1 - 6.5)	3 (2 - 8)	63 (72)	1 (1.7)
Dropped	41 (32)	1:1	0.5 (0.2 - 1.3)	1 (1 - 2)	39 (95)	0
Struck by/against object	136	1.9:1	3.9 (2.3 - 6.5.3)	1 (1 - 2)	91 (70)	3 (2.6)
Indoor injury	20 (15)	2.3:1	2.9 (1.9 - 4.3)	1 (1 - 2)	15 (75)	0
Outdoor fixture	17 (13)	1.8:1	6.3 (3.2 - 6.8)	1 (1 - 2)	15 (88)	0
Perimeter gate	79 (68)	1.8:1	6.3 (2.3 - 6)	1 (1 - 2)	62 (78)	3 (4.9)
Penetrating injury	10 (8.3)	2.3:1	2.4 (2.3 - 4.8)	1 (0.25 - 1.75)	4 (40)	1 (10)
Other and unknown	140 (5)	1.9:1	5.5 (2.1 - 6.3)	1 (1 - 2)	85 (86)	4 (3.6)
Total	2 153	1.7:1	4.5 (2.3 - 6.7)	1 (1 - 2)	1 581 (73)	50 (2.3)

M:F = male:female; IQR = interquartile range; HI = head injury; RTC = road traffic collision; NAI = non-accidental injury

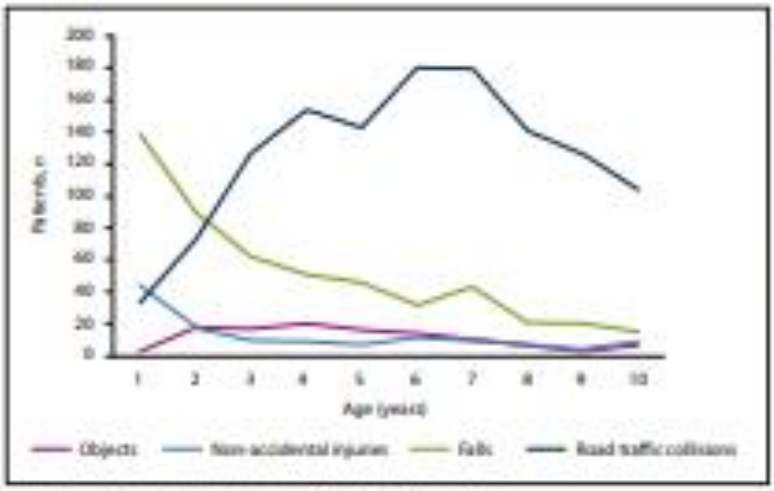

Fig. 3. Frequency of traumatic brain injury type with increasing age.

head injuries the highest mortality of 27% (Table 2). Moving from one severity grade to the next therefore conferred a several-fold increase in mortality. The infant age group had a statistically significant ($p<0.001$) increased vulnerability to severe head injuries, with associated mortality of 55% (n=6/11) compared with 24% (n=32/131) for the rest of the cohort.

CT brain scanning practices

CT brain scans were performed on 935 patients. There were 483 CT scans with reported pathological findings. Of the 261 patients admitted aged <1 year, 44% (n=114/261) underwent CT brain scans, of which 67.5% (n=77/114) revealed pathology. CT scans for moderate and severe injuries revealed pathology in 79% of cases (Table 2).

Outcomes

Eighty-six percent (n=1 861/2 153) of the patients were discharged home, 8% (n=176/2 153) were transferred to other specialties, including orthopaedics, plastic surgery and maxillofacial surgery, for further management, and 2.5% (n=57/2 153) required continued management by the neurosurgery department, of whom 4 died. Thirteen patients were transferred to neighbouring district hospitals for continued rehabilitation. Duration of admission ranged from <24 hours to 132 days. Mean length of stay for patients with isolated head injuries was 2.4 days (range 0.5 - 67), in contrast to 7.2 days (range 1 - 132) for patients with polytrauma with associated TBI. Overall mortality for the cohort was 2.3% (n=50/2 153). RTCs were responsible for 72% (n=36/50) of deaths.

All children who sustained NAIs and those with injuries suggestive of unintentional neglect (infants falling off furniture, children falling out of moving vehicles) were referred on to in-house social workers. All patients with positive CT scan findings (n=481/2 153) had consultations with the neurosurgery service, but only 2.5% required takeover of management. Patients who were admitted for >2 days (n=571/2 153) were additionally assessed by the occupational therapists, physiotherapists and dieticians.

Temporal injury trends

Various temporal patterns were noted in this study. Weekend days incurred the most admissions. A decrease in the frequency of falls and RTCs was noted during winter months, but increased during summer months and school holiday periods. From the start of the study period in 2013 there was an annual decline in admissions, followed by steady increases after 2016 (Fig. 4).

Discussion

Regional epidemiological studies such as this one facilitate the description of injuries peculiar to local environments. In the UK, results of the Confidential Enquiry performed in 2014 assisted in the revision of the National Institute for Health and

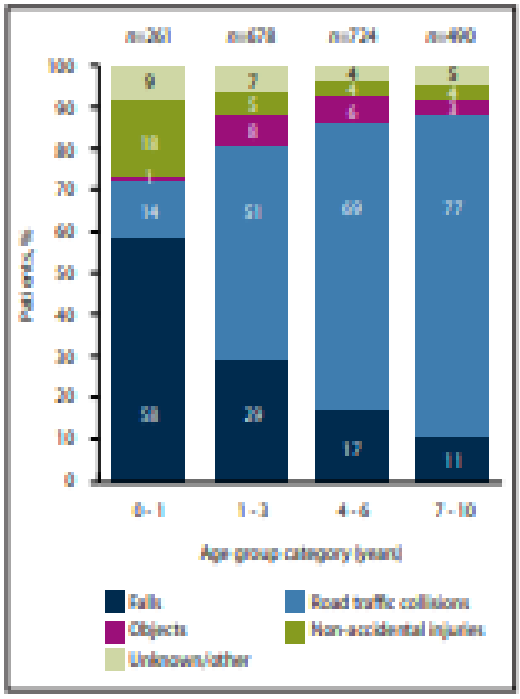

Fig. 2. Proportion of traumatic brain injury frequency by age group category.

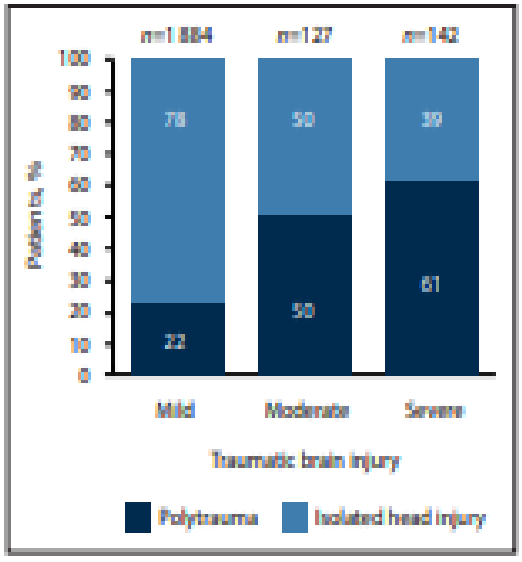

Fig. 3. Correlation between traumatic brain injury severity and polytrauma v. isolated head injury.

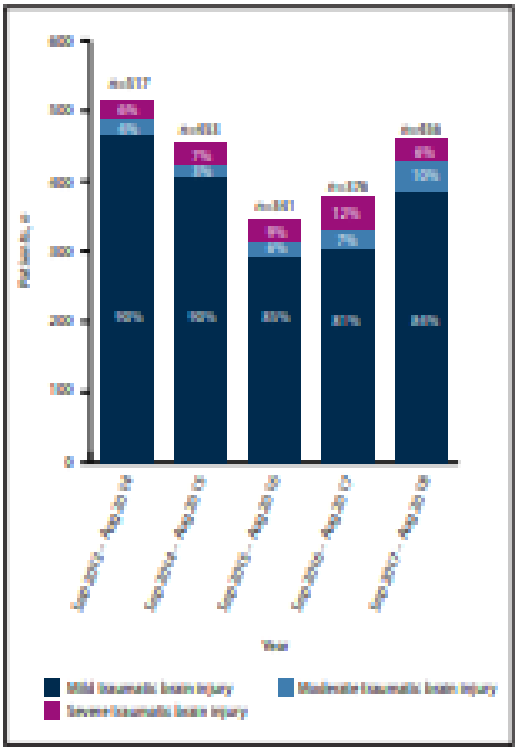

Fig. 4. Annual incidence of traumatic brain injury by severity of injury, September 2013 - August 2018 (date of admission not known for 8 patients).

Care Excellence (NICE) guidelines for paediatric head injuries.[3] An SA-based study from 2007 reported that the major risk factors for TBI included extremes of age, male gender and low socioeconomic status.[7] The implication that young children from impoverished environments are more vulnerable to trauma was paralleled in our findings, as well as in studies from abroad.[14]

Buitendag *et al.*[15] summarised seven studies between 1984 and 2014 pertaining to paediatric TBI in SA and compared these with their own data. To date, reports from Red Cross War Memorial Children's Hospital in Cape Town and the Pietermaritzburg Hospital Complex account for the bulk of published studies.[1,16,17] Publications that focus on TBI in the adult population of Gauteng exist, but the paediatric TBI population of Soweto has not been comprehensively described.[1,18,19]

In our cohort, males incurred injuries more frequently than females. This gender disparity is documented almost ubiquitously both locally and internationally.[1,14,20] For falls from a height, males were also more prevalent, with a male/female ratio of 2.8:1, perhaps reflecting increased risk-taking behaviour of boys.[21]

Similar to other low- and middle-income countries (LMICs), pedestrian-vehicle collisions were the dominant cause for admissions, contrasting with higher-income countries, where falls occurred with greater frequency.[1,20,22] Injuries reported in the present study most frequently occurred outdoors, in contrast to many other studies reporting injuries occurring more frequently in the home or while at school.[1,23,24] This finding may be a reflection of the socioeconomics of the region: children play outdoors in the absence of suitable supervised recreational areas, walk (sometimes long distances) to school without adult supervision, and are often left at home alone while caregivers are at work.

There is mounting evidence that behavioural factors predispose children to pedestrian-vehicle collisions. The cognitive process of interpreting traffic cues and having adequate psychomotor skills to act appropriately may not be sufficiently developed in children aged <10 years. A significant number of RTCs are reportedly due to acts of 'darting out' into streets or 'dashing across intersections'.[25] This impulsive decision-making may predispose younger children to the higher incidence of pedestrian-vehicle collisions as noted in this study. Observations demonstrating that impulsive behaviour is normal for children aged <10 years bring into question the efficacy of child-directed education in this age group and motivate for added awareness programmes involving driver behaviour. Infrastructure

Table 2. Effects of traumatic brain injury severity on presentation, CT scanning practices and outcomes

Parameter	Mild TBI (GCS 13 - 15)	Moderate TBI (GCS 8 - 12)	Severe TBI (GCS 3 - 7)	Total
Total admissions, n (%)	1 899 (87)	127 (6)	142 (7)	2 153
0 - 12 months	245 (94)	5 (2)	11 (4)	261
1 - 3 years	503 (86)	48 (7)	47 (7)	678
4 - 6 years	638 (87)	43 (6)	51 (7)	728
7 - 10 years	426 (87)	31 (6.3)	33 (6.7)	490
Isolated HI, n (%)	1 462 (78)	64 (58)	56 (39)	1 582
Polytrauma, n (%)	422 (22)	63 (58)	86 (61)	571
Gender, n (%):				
Male	1 170 (87)	80 (6)	95 (7)	1 350
Female	714 (88)	42 (5)	47 (6)	803
M/F ratio	1.6:1	2:1	2:1	1.7:1
Mechanism of injury, n (%)				
RTC	1 059 (83)	180 (8)	189 (9)	1 268
Fall	490 (95)	13 (2)	15 (3)	521
NAI	118 (92)	3 (2)	7 (6)	128
Struck by/against object	104 (98)	6 (5)	6 (5)	136
Penetrating injury	6 (60)	3 (30)	1 (10)	10
Other/unknown	104 (94.5)	2 (1.8)	4 (3.6)	110
CT performed, n (%)	676 (36)	126 (99)	132 (93)	934
0 - 12 months	108 (41)	5 (100)	9 (82)*	114
1 - 3 years	107 (32)	47 (97)*	46 (97)	280
4 - 6 years	233 (36)	43 (100)	47 (95)*	323
7 - 10 years	156 (36)	31 (100)	30 (91)*	217
Abnormal CT result, n (%)	278 (41)	80 (63)	125 (95)	483
0 - 12 months	65 (65)*	3 (60)	9 (100)	77
1 - 3 years	68 (32)*	26 (56)	44 (96)	138
4 - 6 years	73 (36)*	26 (53)**	46 (93)	145
7 - 10 years	72 (41)**	25 (79)	26 (92)	123
Mortality, n (%)	7 (0.4)	5 (4)	38 (27)	50
Age group				
0 - 12 months	1 (0.4)	0	6 (55)	7
1 - 3 years	2 (0.5)	4 (11)	12 (23)	18
4 - 6 years	3 (0.2)	0	12 (26)	15
7 - 10 years	1 (0.5)	1 (2)	8 (25)	10
Isolated HI v. polytrauma				
Isolated HI	1 (2)	2 (4)	12 (24)	15 (30)
Polytrauma	6 (12)	3 (6)	26 (52)	35 (70)
Admission (days), median (IQR), range	1 (1 - 3), 0.5 - 47	5 (2 - 11), 0.5 - 41	11 (1 - 28), 0.5 - 132	1 (1 - 3), 0.5 - 132

CT = computed tomography; TBI = moderate brain injury; HI = head injury; GCS = Glasgow Coma Scale; M/F = male/female; RTC = road traffic collision; NAI = non-accidental injury; IQR = interquartile range.
*1 children died prior to imaging.
*2 child died during resuscitation.
*3 children died prior to imaging.
*4 children died prior to imaging.
Technical problems prevented opening of images and loss of motion: *1 studies lost, *2 studies lost, **1 study lost, **4 studies lost.

modification such as traffic calming structures in high-risk areas, including near schools and in residential areas, may offer some reprieve.

In keeping with other LMICs, injuries due to precarious household infrastructure were common.[7,10] NAI presents a serious concern, as this category carried a 4% mortality (double that of the entire cohort). Children under a year of age were most frequently affected by NAI, a finding paralleled in other studies.[7,10,11]

The need to identify a clinically important injury in mild TBI patients must be balanced against the risk of unnecessary exposure to ionising radiation from CT brain scans.[12,13] Internationally, various algorithms have been developed to help address this.[14] We reported a CT brain scanning rate of 36% for mild TBI, of which 41% identified pathology. Owing to resource constraints in our institution, children were frequently admitted for observation and escalated to a CT scan if the need arose. These are conservative figures compared with higher-income countries[15,16] however, for this cohort, this strategy did not incur adverse outcomes.

The decrease in TBI admissions in 2015 - 2016 may have occurred for several reasons. The most recent regional population census reported a decrease in population numbers and birth rates for the area during that period.[17] Simultaneously, a primary-level hospital was opened in Soweto in 2014, diverting minor injuries from CHBAH. The steady increase in TBI admissions that followed

from 2016 may reflect a broader cyclical population pattern in the region, a recovering population growth, or the possibility that the new primary-level institution had become saturated. An increase in RTCs was noted in the summer months and over periods of school holidays. As in other reports, weekend periods incurred higher admission rates. With the exception of NAI, which was consistently reported throughout the year, the temporal pattern in paediatric TBI noted here mirrors previously reported seasonal variability in injury patterns in Soweto.[19]

Children under a year of age are completely dependent on their caregivers. Caregivers in turn may not adapt their level of supervision to the child's evolving motor development. Infants are therefore vulnerable to falls from surfaces (furniture) that they are placed on. They are more likely than older children to be dropped by caregivers and siblings, and carry a higher risk of NAI. Infants with mild TBI incur higher rates of CT-positive pathology, and their risk of mortality in severe TBI is significantly increased compared with older children. Perhaps primary injury prevention strategies for this age group can be integrated into educational programmes aimed at mothers attending antenatal clinics and caregivers at well-baby clinics.

It is widely accepted that mild TBI can result in long-term neurocognitive sequelae.[20,21,22] To assess this in the CHBAH catchment area, we undertook a collaborative prospective study to assess neurocognitive abilities of mildly head-injured children compared with age-matched uninjured children from the same community. Together with the University of the Witwatersrand psychology department and in association with Oxford University, the THINK trial (Traumatic Head Injury: Neurocognitive assessment in Kids) was initiated, based on the population represented in this cohort. Preliminary reports suggest that elements such as speed of processing abilities may be affected following mild TBI, which can have a knock-on effect with regard to future cognitive development and scholastic capabilities, creating further difficulties in the lives of already marginalised children.

Study limitations

The study was a retrospective analysis of information contained in a database and supplemented by case files. Because of language barriers and young age of children, mechanism of injury could not be identified for 85 patients, resulting in some attrition of data. The study inevitably excludes children who died on the scene from their injuries, and patients who may have been seen by feeder hospitals and clinics and managed there. The cut-off admission age was 10 years, which is not representative of the paediatric population, as it is difficult to make comparisons with findings from other national centres.

Conclusions

Paediatric TBI was demonstrated to be a resource-intensive public health concern. Increased vulnerability of infants to TBI was identified, and the prevalence of RTCs was highlighted as a necessary target for primary prevention. Antenatal clinics, schools and local clinics could be considered as points of contact for this purpose. Further research into possible primary prevention solutions specific to Soweto is needed. We hope that the results from the THINK study will identify modifiable targets for early rehabilitation to curb long-term sequelae of mild TBI.

Declaration. The research for this study was done in partial fulfilment of the requirements for VIs Mbiki (Paediatric Surgery) degree at the University of the Witwatersrand.

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Author contributions. VI: conceptualised the study; designed the study, collected, analysed and interpreted data, and drafted the manuscript. PNF: assisted with study design, data analysis and critical revision of the manuscript. CvR: assisted in data collection and management and manuscript review. KvR: assisted in data collection and management and manuscript review; and JAI: contributed to conceptualisation and design of the study, and critical review of the manuscript. All the authors approved the final manuscript.

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Appendix 6: Second accepted manuscript

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The epidemiology of paediatric electrical injuries in a South African township

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ABSTRACT

Introduction: In South Africa 16% of inhabitants live in informal dwellings with no running water or electricity. Access to electricity may be improvised by redirecting current from existing fixtures. Injuries from contact with connecting wires are known to occur but are scarcely described.

Objectives: To describe the epidemiology, presentation and management of electrical burn injuries experienced by Soweto children presenting to Chris Hani Baragwanath Academic Hospital.

Materials and methods: A retrospective review of records for children with a diagnosis of an electrical injury between September 2013 and August 2016 was performed.

Results: All children presenting with a history of an electrical injury were admitted. 103 cases were included in the study. 91% were low-voltage injuries with no mortalities, and 9% were high-voltage injuries with a 67% mortality rate. Mean age at presentation was 4.5 years. 81% of injuries were caused by outside wires and other illegal installations. There was a decreased frequency of injuries during the winter months. 71% had biochemistry derangements. Total body surface area affected ranged from 0% to 76%.

Conclusion: The incidence of electrical injuries in this study was 7% of all burns related admissions. Injuries sustained carried significant morbidity and mortality. The dominant mechanism of injury in this study can be targeted in primary prevention strategies.

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1. Introduction

Electrical injuries account for 2–4% of all paediatric burns admissions worldwide, and result in significant morbidity and mortality [1–4]. In the adult population most electrical injuries are sustained at the workplace, with certain vocations being predisposed [2,5,6]. With children, injuries commonly occur in one of two scenarios: younger children who sustain low voltage injuries in the home as a result of inserting objects into outlets or biting cords, and older children who sustain injuries outdoors while playing and engaging in risk-taking behaviours [3,4,7–9].

Electrical injuries (EI) are described as high-voltage, low-voltage or lightning injuries. If the point of contact supplies 1000 V or greater it is considered high-voltage (HV), and if it supplies less than 1000 V, it is considered low-voltage (LV) [1–3]. Lightning injuries are classified as high-voltage injuries [2]. The effects of contact with electricity are determined by a variety of factors including voltage, resistance, amperage, polarity of the current, duration of contact, and pathway taken by the current through the body [10–12]. The voltage supplied by household plugs and installations varies from country to country. Domestic electrical supply varies between 120 V in the US and Canada, to 240 V in Europe, Asia, Australia and South Africa [2,7,13–15].

In Soweto, housing ranges from freestanding homes with all amenities, to neighbourhoods of informal dwellings (known as shacks) lacking utilities such as plumbing, water supply and electricity. Electrification of some informal dwellings is improvised using nearby formal electrified structures such as street-lights and electricity meters (Figs. 1 and 2). Wires of various lengths are connected from the permanent structures to reach the informal dwellings.

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Fig. 1. Diverting power from street-lights using wires and tape.



Fig. 2. Electrified wires loosely buried under soil in the street, branching to homesteads.

Although injuries related to contact with unauthorized electrified wires and tampered structures are routinely seen in South African hospitals and clinics, data regarding such injuries are scanty. Hence, this study sought to analyse the nature, acute management and outcomes of electrical injuries as experienced by the paediatric population residing in the township of Soweto.

2. Materials and methods

This is a cross-sectional, single centre retrospective review of patient files for all children admitted to Chris Hani Baragwanath Academic Hospital (CHBAH) Paediatric Burns Unit (PBU) with a diagnosis of an electrical injury over a 36-month period, between September 2013 and August 2016.

2.1. Study population

The department of Paediatric Surgery, Chris Hani Baragwanath Academic Hospital caters for children up to 10 years of age affected by all surgical conditions, including traumatic injuries. There is a dedicated Paediatric Burns Unit with 18 ward beds as well as a seven-bed ICU managed by Paediatric Intensivists. All cases of suspected electrical injuries presenting to CHBAH are admitted to the PBU. On arrival, patients are clinically assessed, total body surface area (TBSA) estimated using the Lund Browder chart, and resuscitated as per Advanced Trauma Life Support (ATLS) guidelines. Vital parameters, 12-lead electrocardiogram (ECG), urine dipstick and blood analyses (including urea and BUN, creatine kinase and its myocardium- specific isoenzyme, troponin T, full blood count) are performed.

Patients who experienced electrical injuries during the study period were identified through the departmental electronic database and ward admission records. Of the 1687 burns admissions, 1449 admissions were from the Soweto area. Of these, 107 admissions were identified as electrical injuries.

All patients presenting within 24 h of sustaining an electrical injury were included in the study. Three patients presented more than 24 h post injury, having undergone initial management elsewhere and were excluded. One patient suffered burns sustained in a shack fire initiated by faulty wiring. This patient was also excluded as injuries were likely due to flame burns. Therefore, 103 patients were included.

2.2. Data collection

For each patient, the information collected included demographics, mechanism of injury, site and extent of burn, initial laboratory and side room investigations, length of hospital stay, and outcome expressed as discharge from the facility or death. 2 children demised shortly after arrival to CHBAH thus investigations were incomplete.

2.3. Statistical analysis

Standard descriptive statistics were used to analyze the data. Mean and SD (standard deviation) were used to describe normally distributed continuous variables, and proportion used for categorical variables. Median and IQR (Interquartile Range) were used to describe skewed data. Continuous variables were checked for normal distribution and the Wilcoxon signed-rank test was used to analyse skewed data. Fisher's exact test was used when there were less than 5 observations. Stata (StataCorp. 2014 LP, Texas USA) software was used for computations. P values less than 0.05 were considered statistically significant.

3. Results

Of the 103 patients included in the cohort, 94 children experienced low-voltage injuries and 9 children sustained high-voltage injuries. During the study period, there were no lightning injuries recorded.

3.1. Age, sex and outcomes

In the low-voltage group, there was a male to female (M:F) ratio of 2:1, mean age at injury was 4.5 years and no mortalities occurred. Of the 9 high-voltage exposures in this cohort, there was only 1 female (4 years old), the mean age was 5 years and mortality was 67%. Male predominance for electrical injuries has previously been reported [5,16]. Two of the patients in the high-voltage group demised shortly after arrival to the hospital, and another

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high-voltage patient required cardio-pulmonary resuscitation on arrival but survived to discharge. Children under 5 years accounted for 25% of admissions, and the youngest patient in the cohort was 10 months of age (Table 1).

3.2. Mechanism of injury

Information regarding mechanism of injury was available for 76 patients. One patient had contact with a wall socket, 11 sustained an electrical injury while contacting an appliance, 54 patients sustained injuries from contact with exposed outdoor wires. These contacts resulted in low-voltage type injuries. Nine patients had contact with high voltage installations. Three children sustained injuries by accidental contact with high voltage cables, 2 children were in close proximity to a prepaid meter explosion, and 4 children had access to unlocked electrical boxes. Thus, 83% of injuries were sustained through outdoor exposed wires and structures which should not have been accessible to children. This is unlike other reports, where the majority of injuries are sustained in homes [4,7,12,17,18].

3.3. Effect of housing type and season

At least 43% of the admitted children came from areas of informal housing. A further 30% of the children came from areas of "mixed" housing, where informal dwellings are constructed in yards and rented. Only 27% of children admitted for electrical injuries lived in homes with formal electrification (Fig. 3). Over the three-year study period there was a seasonal variation in incidence, with most electrical injuries sustained in the South African summer months. In addition, a yearly increase in incidence was also identified (Fig. 4). A seasonal predominance of electrical injuries was also noted in a study from New Delhi [15].

4. Extent of injuries

A significant difference in the extent of injuries sustained between high-voltage and low-voltage injured children was noted. In the low-voltage group, the mean affected total-body-surface-area was 2.45%, ranging from 0 to 15% TBSA. Twelve of the patients admitted for low-voltage contact had no visible burn marks. From this group, one child was reported to have touched a wall socket outlet, 7 children had contact with outdoor wires and 4 children had touched exposed wires from appliances connected using illegal connections. Seven reported loss of consciousness, and 8 had raised creatine kinase levels suggestive of an electrical injury despite lack of physical findings. Sixty three of the 94 low-voltage injured patients had burns to the hands, one requiring amputation of the affected digit and a further 4 patients requiring surgical debridement of their wounds. For the high-voltage injured group the mean total-body-surface-area was 36% with a range of 4–76%. Injury size discrepancy between low-voltage and high-voltage injuries was also described by Kumar et al. [5]. All high-voltage injured patients who survived past initial resuscitation required ICU admission. Two children with 45% total-body-surface-area high-voltage injuries (aged 13 months and 17 months old respectively) required upper limb escharotomies, the latter required a further 3 wound debridements and 2 split skin grafts

Table 1
Age Distribution by injury type and gender.

Age-Group	N° (% total)	High-voltage	Low-voltage	Male	Female
<1 year	4 (3.9)	0	4	2	2
1–3 years	33 (38.1)	2	28	18	12
4–6 years	14 (13)	1	11	25	9
7–10 years	14 (13)	6	10	27	7

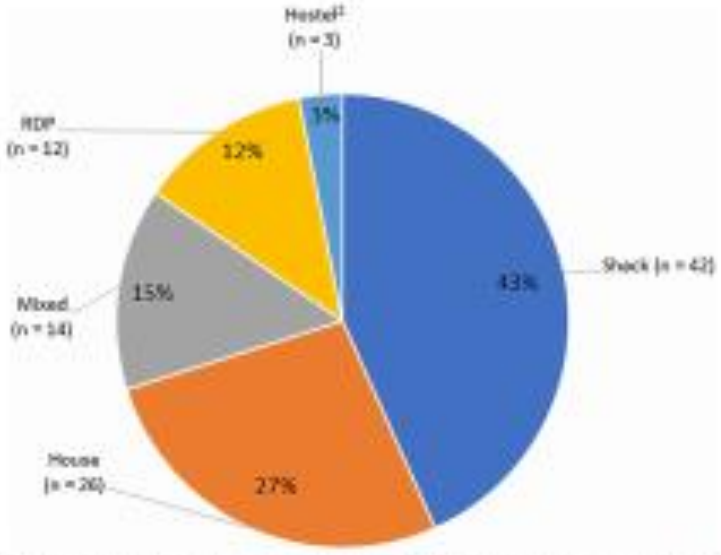

Fig. 3. Distribution of patients by type of housing the children reside in RDP housing: Reconstruction and Development Program: subsidised low-cost housing. Hostel: historically single-sex dormitory-like housing for migrant labourers and miners, more recently some house families.

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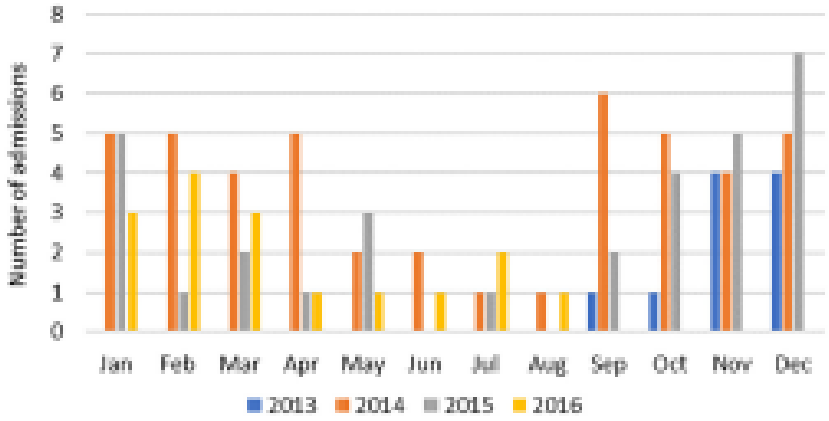

Fig. 4. Number of admissions by month: September 2013 to August 2016 demonstrating seasonal variation of injuries.

but demised after 58 days of hospitalisation due to nosocomial sepsis. In total, 6 of the 9 high-voltage injured children required surgical interventions in the form of escharotomies, wound debridements and split skin grafting. All wounds were managed with serial dressings until wound healing was complete.

Evidence of loss of consciousness (LOC) at the scene was reported for 89% of high-voltage injuries and 13% of low-voltage injured children. Three patients presented with history of seizures post electrical contact (Table 2).

5. Laboratory and side-room investigations

It is our institution's practice to perform electrocardiogram (ECG) tracings for the first 24 h for all electrical injuries. For this cohort, derangements in ECG tracings included tachycardia, sinus arrhythmias, ST segment elevation and one case of ventricular fibrillation. Abnormalities were noted to be transient and had all reverted to sinus rhythm within the 24h observation period. The case of ventricular fibrillation (due to a high-voltage contact) reverted to sinus rhythm after the immediate resuscitation period and did not have further cardiac consequences during the hospitalization period.

Microscopic haematuria based on urine dipstick was only reported in 5 patients: 3 from the high-voltage injured children, and only 2 from the low-voltage injured group. For the low-voltage injured patients this had reverted to normal within 12 h of admission. For the high-voltage injured patients, microscopic haematuria persisted past 12 h from admission. The presentation of haematuria between the two groups was statistically significant.

Creatine kinase (CK) results were available for 75 patients. For the low-voltage injured patients the lowest value was 94 U/L and highest was 2556 U/L. In the high-voltage injured group, results ranged between 255 U/L and 1810 U/L. The CK-MB was reported for 58 patients. Results were not remarkable and there was no statistically significant difference between the two groups. Troponin T results were available for 40 patients but gave inconsistent results. Our laboratory is unable to detect levels below 3 ng/L and used <15 ng/L as a rule-out level for acute cardiac pathology. Some authors suggest a level greater than 5.9 ng/L is a good predictor of myocardial damage with adverse effects noted for the paediatric cardiac population in the immediate post-operative period [19]. As noted in other publications, results for both parameters (CK-MB and Troponin T) were neither clinically in keeping with the condition of patients nor their ECG results [3,20]. For the high-voltage injured patient who received cardio-pulmonary resuscitation with chest compressions, both CK-MB (21.35 μg/L) and troponin T (267 ng/L) levels were markedly elevated, but sampling occurred after resuscitation, once the patient had stabilized (Table 3).

6. Discussion

In this cohort, electrical injuries comprised 7% of total burns admissions. Where mechanism of injury was known, 71% of injuries were sustained from contact with unauthorized electrified wires or open electrical boxes. Although electrical injuries are classified as high-voltage or low-voltage, in this environment knowledge of the power source is more elusive. In the case of unauthorized installations the following is known (from the official utilities supplier): above-ground installations such as pilons are high-voltage and highly dangerous. Only ground-level exchange stations and street-lights can be used for redirecting electricity, as voltage in these fixtures has already been stepped down. Voltage of the contact can thus be surmised from the history and clinical presentation.

Table 2
Summary of demographics, injury size, length of hospitalization, and outcome for LV versus HV injured patients.

Parameter	Low-voltage (N° = 94)	High-voltage (N° = 9)	Total N° = 103
Female (%)	31 (97)	1 (3)	32 (31)
Male (%)	63 (89)	8 (11)	71 (69)
M:F Ratio	2:1	8:1	2.2:1
Mean Age (months) (SD)	54.5 (31.88)	60.3 (30.95)	55.03 (31.68)
Mean burn size in % TBSA (SD) (min–max in %TBSA)	2.45 (3.93) (0–15)	36 (27.81) (4–76)	5.85 (13.67) (0–76)
Number of patients with No Visible wounds (%)	12 (12.8)	0 (0)	12 (11.6)
Median hospitalization in days (SD) (min–max days)	2 (13.93) (0–80)	3 (20.7) (0–58)	2 (14.71) (0–80)
Number of mortalities (%)	0 (0)	6 (67)	6 (5.8)

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Table 3
Summary of clinical parameters and laboratory findings.

Parameter	Low-voltage (N = 94)	High-voltage (N = 9)	TOTAL (N = 103)	P
Number of patients reporting Seizures (%)	3 (3)	0 (0)	3 (2.9)	0.55
Number of patients reporting Loss of consciousness (%)	21 (23)	8 (89)	29 (28)	0.032
Number of patients with Haematuria (%)	2 (2)	3 (33)	5 (4.8)	0.005
Number of patients with ECG abnormalities	4 (4)	2 (22)	6 (5.8)	0.098
CK; median, IQR (75 records) (N 80–158 U/L)	360 (175–763)	1081 (253–1521)	360 (200–854)	0.14
CK-MB; median, IQR (N 0–4.88 μg/L)	12 (6.3 – 28.2)	77 (21–169)	13 (7 – 28)	0.07
Troponin T; median, IQR (N < 3 ng/L)	4 (2–45)	4 (3–367)	4 (2 – 6.75)	0.73

Four mechanisms by which electricity causes injury are described: the direct effect of the electrical current on tissues, burns (thermal and flash burns), mechanical injury and electroporation [3,6,21]. All 4 mechanisms described can account for the range of injuries described in this study.

Electrical current causes predictable injuries to specific organ systems as evidenced by cardiac arrhythmias, dermal injuries, rhabdomyolysis and acute kidney injury. Altered mentation and loss of consciousness may also occur because CSF is known to offer low resistance and is a good conductor of electrical current [2,3,6,21].

The effects of current are further influenced by whether the current is alternating or direct in nature. Direct current is only found in industrial installations and high-voltage power lines. It can cause a single muscle contraction that throws the victim away from the electrical source, whereas alternating current causes a sustained muscle contraction which may prevent the victim from letting go of the source of electricity for an extended period of time. [2,13,14,21,22]. In this cohort ECG abnormalities were noted in 6 of the 50 available records. Sinus rhythm returned within 24 h. Authors looking at ECG changes following electrical injuries have concluded that ongoing monitoring is not necessary if ECG was normal on presentation [1,11,13,15]. Our findings parallel this observation.

Eighty eight percent of patients in this series experienced a thermal burn. For the low-voltage injuries burns were limited to the point of contact with electrical current as evidenced by the pattern of the injuries (Figs. 5 and 6), whereas the high-voltage burns were more extensive with higher total body surface area affected.



Fig. 5. 5 year old male sustained linear burn injuries to the right hand, as a result of grasping exposed electrified wires.



Fig. 6. 1 year old female sustained full thickness linear burn to face and nose while being carried and accidentally caught on a wire between two trees.

High-voltage contacts can result in a burn injury in one of three ways: flame burn (from ignited clothing), thermal burn (from heat generated by an arc) and electrical current (from contact with the arc) [2,22].

Mechanical injuries can be caused from falls secondary to loss of consciousness, muscle tetany, unsafe environment, or from being propelled by a direct current contact. No severe mechanical injuries were reported in this cohort, however, 27% of patients reported loss of consciousness and 3% reported seizures, placing these patients at increased risk for this mechanism of injury.

Electroporation is the term used to describe pore formation in the lipid bilayer of the cell membrane when an electric field is applied to it. Pores in the lipid bilayer membrane remain open for the duration of electrical contact. During this time, the cell attempts to maintain its normal ionic gradient, until the electric field is removed, after which the cell will attempt to repair itself. This process injures the cell and can even result in cell death. Electroporation can cause significant skeletal muscle necrosis without visible thermal changes of the overlying skin [6,23]. In such cases, raised creatine kinase in the absence of a visible burn when an electrical injury is suspected may assist in corroborating the injury. Electrical injuries can also cause rhabdomyolysis through the combination of tetanic contraction of the muscles and direct effects of electricity on muscle fibres. If sufficient muscle injury occurs, it can result in subsequent kidney injury [2,17,24]. Creatine kinase was measured in 80 patients. The elevations did not correlate with severity of burn injury, expressed as a percentage of total body surface area. This finding was also noted by other authors [7,10]. Tomkins reported that delayed detection of myoglobinuria and limited fluid resuscitation contributed to the development of acute renal

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failure in a patient in their series [7]. In our series, 5% of patients tested positive for microscopic haematuria on urine dipstick. The low-voltage injured patients cleared the haematuria within 24 h of management, with no adverse sequelae. Although the traditional dipstick methods do not differentiate between haemoglobin, myoglobin or red blood cells, positive tests alert the clinician to potential pathology, and further investigations can then be requested [25].

While low-voltage injured children were admitted for short durations, based on the above findings, and on reports from above-mentioned studies, admission times can further be safely reduced. High-voltage injured children had an overall devastating outcome.

There were several limitations to this study that warrant mentioning. This was a single-centre retrospective review. Initial resuscitation and management were conducted without a standardized protocol, thus some tests were occasionally omitted at the discretion of the initial attending doctor. In addition, there was no long-term follow-up of the patients once wounds were healed. Other studies report long term sequelae including permanent paraesthesias of injured areas, neuropsychological symptoms including problems with attention, concentration and short-term memory but this was not assessed in these patients [4,9,26].

7. Conclusion

For inhabitants of informal housing electricity allows access to lighting, and a safer energy source for cooking and heating water for bathing than open flame sources [27]. At present, no affordable alternative supply of electricity is available to this population. In part, this is because informal settlements are not always accessible to existing infrastructure and the lack of formal town-planning in these areas. In addition, urban growth is exceeding local municipal capabilities [28].

Electrical injuries in children living in the Chris Hani Baragwanath Academic Hospital catchment area were previously regarded as infrequent. This study identified a high incidence of electrical injuries with significant morbidity and mortality. Although 103 patients were included in the study, this represents a small portion of what is experienced in our catchment area. Children injured while playing unsupervised may not report injuries. Care-givers often take children to nearby primary clinics due to the cost of transportation and erratic emergency services. Secondary level hospitals in the Chris Hani Baragwanath Academic Hospital catchment area manage electrical injuries without referring them on. Better long-term follow up with regards to cardiac, renal, musculoskeletal and neurocognitive outcomes is needed. It is hoped that these findings will aid in the development of a standardized management algorithm tailored to resource restrained environments, as well as prevention programs directed towards protecting this vulnerable group in our population.

8. Ethics

Ethics is obtained from the University of the Witwatersrand Human Research Ethics Committee (Medical) Clearance Certificate no: M160507.

9. Patient consent

Informed consent forms were signed by parents of participants.

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Appendix 7: Co-author approvals

Declaration: Student's contribution to articles and agreement of co-authors

I, Vered Lack, student number 9402066y, declare that this Research Report is my own work and that I contributed adequately towards research findings published in the articles stated below which are included in my Research Report .

Signature of Student …… **Date**……19/04/2021……

Name of Primary Supervisor……Prof J Loveland

Signature of Primary Supervisor **Date**……19/04/2021……

Agreement by co-authors: By signing this declaration, the co-authors listed below agree to the use of the article(s) by the student as part of her Research Report. In cases where the student is not the 1st author of a published article, the primary supervisor must explain (under comments) why the student is entitled to use the paper for his/her degree purposes.

Article 1: Title: . The epidemiology of paediatric electrical injuries in a South African township.

Journal name, year, volume and page numbers: Burns Open. 2020;4(2):53-9.

Authors	Name	Signature	Date
1st author	V Lack		19/04/2021
2nd author	M Esteves		19/04/2021
3rd author	LU Nnaji		19/04/2021
4th author	JA Loveland		2021/04/19
5th author	C Westgarth-Taylor		19/04/2021

Comments by primary supervisor:

……

Article 2: Title: The epidemiology of traumatic brain injuries sustained by children under ten years of age presenting to a tertiary level hospital in Soweto.

Journal name, year, volume and page numbers: SAMJ (to be printed in August 2021 edition)

Authors	Name	Signature	Date
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3rd author	K van Rensburg		19/04/2021
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