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Demographic Characteristics, Incidence Trends, and Treatment Outcomes of Pediatric Traumatic Brain Injury (PTBI) at Bugando Medical Center

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Abstract

Objective: To determine the demographic characteristics, incidence trends, and treatment outcomes of Pediatric Traumatic Brain Injury at Bugando Medical Center (BMC). Methods: A retrospective hospital based study was conducted, data were extracted from the BMC emergency and neurosurgical electronic registers for all patients aged less than 18 years in a three year study between January 2020 to December 2022. Results: Among 302 pediatric patients, male to female ratio of 1.5:1, 109 were attended as outpatient and were discharged while 193 were subsequently admitted. Children were categorized into the following age groups: children < 1 year (4), 1 - 3 years (125), 4 - 6 years (120), 7 - 10 years (51), and 11 - 18 years (2). Motor accidents was the leading mode of injury 178 (58.9%), followed by falling from heights 77 (25.5%), interpersonal violence 8.3%, hit by heavy object 6% and animal kick, assault, child abuse each contributed 0.7%. The incidences of pTBI were rapidly increasing with time in 2020, (39) vs 198 children equal to five folds' increase by 2022. Rural-urban ratio was 56.3% vs 43.7%. In this cohort, at discharge, 90 had good outcomes (29.8%), neurological deficits 3 (1%), milestone regression and 10 deadd whereas during the one month follow-up, 168 children (55.6%) were had good outcome and 2 children had died making the mortality rate at 4% in this series. Conclusion: In this single-center retrospective study, the annual incidence trends exponentially rose over 5 folds in three years with an annual incidence of 0.756 per 1000 cases per hospital admission. Children 1 - 3 years old were the most affected group, and Road Traffic Accidents (RTAs) were the most common cause of pediatric traumatic brain in-

jury, similar to international reports. Efforts must be made to enhance awareness among parents and the public health system to foster more measures to mitigate this public burden.

Keywords

Pediatric Traumatic Brain Injury, Bugando Medical Center, Road Traffic Accidents

1. Introduction

Traumatic brain injury is a global public health concern affecting the pediatric population and is one of the leading causes of disability and mortality in children and young adults worldwide [1] [2]. The global incidence rate of pediatric traumatic brain injury has been reported at 939 cases per 100,000 children, with boys outnumbering girls in most studies, with mixed age distribution, although a bimodal distribution of children below two years of age and older ones aged between 13 and 17 years old have been reported [3].

In Tanzania, Road Traffic Accidents (RTAs) have been reported as the leading cause of Traumatic Brain Injury (TBI) [4]. Although other mechanisms of injury have been repeatedly mentioned across the dearth of TBI literature, including but not limited to, falls from height, domestic violence, childhood abuse, unprotected child labor [5], animal assaults, mishaps injuries from collapsing buildings, sports [6], iatrogenic injuries in newborn, and self-inflicted injuries [7].

At our institution, in this era of continued improvement in pre-hospital care [8] and modern imaging, most pediatric patients with TBI undergo emergency evaluation and are treated according to standard guidelines [9] along with multidisciplinary management [10].

In the northern western zone of Tanzania, TBI is among the leading causes of emergency visits and hospital admissions at a tertiary institution as reported in earlier studies by Chalya and colleagues [11] [12]. However, there is a paucity of published data regarding the burden of TBI among the pediatric population in this region. Hence, this study aims to identify the incidence trends and epidemiological characteristics of Pediatric TBI (PTBI) in the region using hospital-based data evaluation to generate an evidence-based algorithm to inform healthcare providers, policymakers, and public health officials of the magnitude, annual incidence trends, and burden of pediatric traumatic brain injury.

2. Methodology

This study is an observational cohort study based on retrospectively collected data from an institutional electric medical information system covering all pediatric TBI patients attended at a tertiary consultant institution in the lake zone region of Northwest Tanzania. All children less than or equal to 18 years of age who were

attended to at the emergency department and or admitted to the neurosurgery inpatient ward and diagnosed to have Traumatic Brain Injury (TBI) at our institution from January 2020 to December 2022 were included.

3. Data Analysis Procedure and Statistical Analysis

Demographics, date of injury, mechanism of injury, the severity of TBI based on the Glasgow Coma Scale (GCS), radiological findings, clinical management course, and short-term outcomes were collected was entered in a Microsoft Excel sheet. Data was reviewed by running preliminary frequencies of all the variables to check for entry inaccuracies. All incorrect data was double-checked with the questionnaire after which all wrong entries were corrected and coded for quantitative data analysis. Data was then analyzed by SPSS software. The study involved all children aged between 0 to less than or equal to 18 years old, and during analysis, files were categorized by age groups as follows infants (0 - 12 months), toddlers (1 - 3 years old) preschoolers (4 - 6 years old) school-going (7 - 10 years old), and young adolescents (11 - 18 years old). With the use of the SPSS, the following was computed: the annual incidence of pTBI for each year, the age-stratified incidence for each age group, the most commonly identified diagnosis, its incidence, incidence of admission, pediatric population who were treated as outpatient in the emergency department, the overall trends of pTBI for all three years, the incidence of children who were diagnosed to have other co-morbid visceral and skeletal injuries, proportion of pediatric population who received conservative management and those who required surgical intervention, the incidence of children who at discharge were found to have neurological deficit(s), death rate due to pTBI alone, Categorical variables will be presented by frequency percentages, graphs, and tables. Continuous variables will be described using median and interquartile ranges. Appropriate statistical significance will be accepted as relevant, if $p < 0.05$.

4. Results

4.1. Demographic Data

Between January 2020 and December 2022, a total of 3992 children presented to BMC emergency department due to neurological issues. Among them, 302 children had pTBI and were enrolled in the study. Males were the dominant group of 180 (59.6%), whereas 122 (40.4%) were female. The most affected age group was toddlers 125 (41.4%), followed by preschoolers 120 (39.7%), schoolgoing 51 (16.9%) and 11 - 18 years was 2 (7%) and less than 12 months was 4 (1.3%) as shown in Figure 1. In terms of location, urban comprised 132 (43.7%) whereas rural contributed to 170 (56.3%).

4.2. Annual Incidence Trends of Pediatric Traumatic Brain Injury among Pediatrics

In a cohort of children admitted between 2020 and 2022, the incidence of pTBI increased with time: 2020 39/996 (3.92%), 2021 65/1471 (4.42%), and 2022 198/1525

(13%). The overall percentage of children ever treated at BMC due to pTBI for 3 years was 7.56% among 302 children who are less than or equal 18 years old as shown below in Table 1.

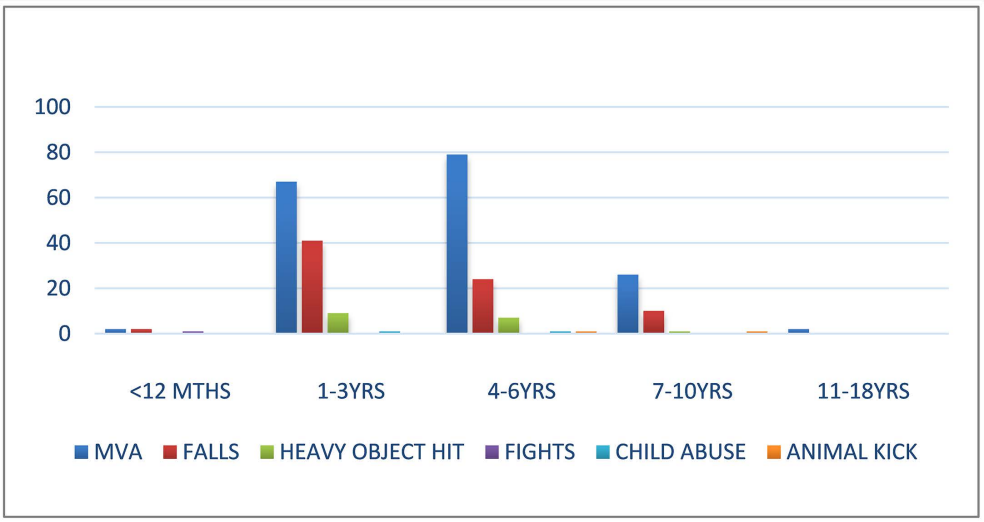

Figure 1. Graph showing the frequency of different modes of injury (MOI) per age group.

Table 1. Showing mechanisms of injury, clinical and radiological characteristics.

Year	Incidence	%	No. of children attending EMD and neurosurgical	Increase rate % per year
JAN-DEC 2020	39	12.9	996	3.92
JAN-DEC 2021	65	21.5	1471	4.42
JAN-DEC 2022	198	65.6	1525	13

4.3. Modes of Injury and Clinical Characteristics of pTBI

Road Traffic Accidents (RTAs) contributed to about 178 (58.9%), falls from height were 77 (25.5%), interpersonal attacks were 25 (8.3%), hit by heavy objects were 18 (6%), and animal kicks and assaults contributed a total of 4 (1.4%). Among the RTAs group, pedestrians contributed 87.6% as compared to passengers (12.4%).

Clinically, most patients presented with mild TBI (GCS 13-15) 159 (52.6 %), followed by moderate TBI (GCS 9-12) 94 (31.1 %) and lastly severe TBI (GCS < 9) 49 (16 %). Most children were clinically diagnosed to have intracerebral injury—227 cases, followed by fracture of the skull—53 cases, then diffuse brain injury—13 cases, intracerebral injury—7 cases, subdural hemorrhage—1 case, and concussion—1 case. After the Non-Enhanced Computed Tomography (NECT) scan, the diagnoses changed drastically. (Table 2)

109 patients did not undergo CT scan due to the mild nature of the head injury and these were discharged as outpatients upon review at the emergency. Among the 193 patients who underwent CT scan, findings are shown in Table 1.

Table 2. Showing clinical diagnoses frequency and the age groups affected.

Variable	N	%
Mechanism of injury		
Road traffic accident	178	58.9
Fall from height	77	25.5
Interpersonal attack	25	8.3
Hit by heavy objects	18	6.0
Animal kick	2	0.7
Assault and child abuse	2	0.7
Glasgow Coma Scale		
Mild	159	52.6
Moderate	94	31.1
Severe	49	16.2
Initial diagnosis		
Intracranial injury	227	75.5
Fracture of skull	53	17.5
Diffuse brain injury	13	4.3
Intracerebral hemorrhage	7	2.3
Subdural hemorrhage	1	0.3
Concussion	1	0.3
Diagnosis after CT Scan		
Concussion	27	8.9
Skull fracture	65	21.5
Cerebral contusion	30	9.9
Extracranial hemorrhage	50	16.9
Intracranial hemorrhage	6	2.0
Diffuse axonal injury	14	4.6
Diffuse cerebral edema	1	3.0
No CT Scan done	109	36.1

4.4. Treatment Outcomes of Pediatric Traumatic Brain Injury

Most of the children were conservatively managed and 31 (10.3%) were treated surgically.

The morbidity due to pTBI contributed to 7.57% of Visits to all emergency and pediatric neurosurgical admissions and had a mortality rate of 3.97%.

Of the 302 children who attended BMC due to pTBI during the first encounter, 142 (47.01%) were normal, 47 (15.56%) had neurological deficits, 5 (1.66%) had milestone regression, 10 (3.31%) children were already dead, and 98 (32.45%) children had missing information about their health status and preservations of

their abilities that were already achieved. On one month follow-up of these children, 168 (55.63%) were normal, 29 (9.6%) had neurological deficits, 3 (0.99%) had milestone regression, and 2 (0.66%) children were dead making a total of 12 (3.97%) deaths due to pTBI and 90 (29.8%) had missing information.

Some children's pTBI was influenced by other comorbid injuries sustained including 72 (24%) children who had skeletal injuries, 36 (12%) children who sustained visceral injuries, 1 (0.3%) child who had polytrauma, and 193 (64%) children who did not succumb to another injury. Table 3 summarizes the treatment outcome findings.

Table 3. Showing summary of treatment outcomes.

Variable	n	%
Treatment modality		
Conservative management	271	89.7
Surgical treatment	31	10.3
Clinical status during admission time		
Normal	142	
Neurological deficit	47	
Milestone regression	5	
Dead	10	
Missing information	98	
One-month follow-up clinical status		
Normal	168	55.6
Neurological deficit	29	9.6
Severe milestone regression	3	1
Death	12	4
Missing information	90	30
Comorbidities		
skeletal injuries	72	24
visceral injuries	36	12
Poly trauma	1	0
No other injury	193	64

5. Discussion

In this study, we have attempted to analyze the incidence trends, identified the demographic patterns and injury mechanisms in our region, and undertook a further analysis of our findings in comparison to the global pediatric TBI literature. In general, the findings in this study of the lake zone region of Mwanza were unsurprisingly largely similar in several aspects to other large referral centers in Tanzania found in Northern Tanzania-Moshi [13], Western Uganda-Mbarara [14] and the African pediatric TBI series as reported in a systematic review by Esene *et al.* [15].

5.1. Demographics and Annual Incidence Rates

In this study, male patients were the majority, a demographic finding consistent with global reports [16] [17]. The median age of this cohort was 4.6 years, and two peak age groups were identified 1 - 3 years and 4 - 6 years, a finding similar to earlier CDC reportson pediatric TBI [18]. The most affected age group was children aged between 1 and 3 years of age, possibly attributed to their reduced ability to anticipate the upcoming danger, similar to the findings of the study done in Soweto, South Africa that also picked an increased rate of childhood pTBI and link it to their poor ability to safeguard themselves[19]. In contrast, a study in Northeastern region of Tanga [20] by RTI showed higher rates among adolescents (13 - 17 years) as compared to children < 5 years (21.5 vs. 14.1 per 1000, $p = 0.039$).

Most children diagnosed with pTBI in this study were from rural areas—170 children (56.3%) as compared to several children from urban areas 132 children (43.7%). This was in contrast to the study in the northeastern Tanzania region of Tanga [20] and findings in Iran [21] where the majority were injured in city areas. This could be related to the fact that children between 13 and 17 years old have an increased curiosity and desire to engage in activities their peers are doing, making them to impulsively engage in risky activities like alcohol and other substance use, predisposing themselves to RTAs and consequently, pediatric Traumatic Brain Injury (pTBI).

Over the three years, we noticed a drastic increase in the incidence of PTBI in resonance with global reports [22]. One possible reason could be due to increase in motorizations, negligence, and poor control of vehicles on the roads [23]. Additionally, the increase could be explained by the improved diagnostics ability both at our institution and nationwide given that all regional hospitals are equipped with CT-scan when compared to the past 5 years, leading to increased early detection, diagnosis, and referrals [24]. Notably, our institution is the only tertiary referral center with cheap neurosurgical-related services within the lake-zone region of Mwanza and plays a potential bias in explaining the three-fold rise in our center amidst other factors.

However, the potential role of the COVID-19 pandemic as a confounding factor that may have influenced access to several health services across the globe [25] [26] including disrupting traffic patterns and hospital admission rates during the 2020-2021 period cannot be underestimated.

Similarly, self-referrals following raised awareness for conditions such as concussion, although these figures could be underestimated by home-treated cases of mild TBI who never report to the hospital. However, the relatively low incidence in 2020-2021 could be attributed to underestimated self-referrals for several reasons such as the paucity of concussions due to a lack of uniformly accepted admission guidelines for mild TBI forms such as concussions which tend to be home-treated. Banu et al similarly noted a low incidence in 2000-2021 period in Southern India and this was attributed to the decongestion of roads and regulation of alcohol sales can decrease TBI occurrence [27]. In contrast, a higher incidence of

TBI hospitalizations was reported in Rwanda during a similar period [28].

5.2. Mechanism of Injury and Radiological Findings

Road traffic accidents were the most common mode of injury 58.9% followed by falls from height 25.5%, a finding in tandem with institutional African pediatric series reported elsewhere in East Africa, West Africa [29] Southern Africa [19]. The increased burden of RTAs could be partly attributed to the economic development which has led to better roads and increased number of vehicles, as reported by the Global status report on road safety [30]. In contrast, Fatma *et al*. reported falls 63.7% vs 18.3% (RTAs) as the most common cause among 985 PBTI patients in a 5-year single-center study in Lebanon [31]. In this study, pedestrians were 7 times more affected in comparison to passengers and this could be explained by the fact that all children below 18 are not allowed to drive, contrary to findings from a systematic review and meta-analysis by Davies *et al*. among 15 African countries where they reported a higher mortality rate among passengers in motorized passengers compared to pedestrian [32]. In the East African region, a variety of road transport means exist including motor vehicles, motorcycles, [33] motor tricycles, and bicycles and have reportedly contributed to the burden of RTAs in this region [23]. A study in Dar es Salaam noted that children were injured pedestrians 93% of the time and were more likely to be injured on small, unpaved side streets than adults [34]. Another study conducted among African countries indicated that human-related factors such as over-taking, speed driving, fatigue, reckless driving, drugs, poor-seat belt use, sleeping, drunk driving, cell phone usage while driving among others were responsible for more than three-fourths (¾) of RTAs in Africa [35].

Notably, 36.1% of the patients with PTBI did not do CT scan imaging. Although this figure correlates with the finding that the majority 52.1% of the cohort had mild TBI hence some were clinically cleared for radiological imaging, the reality remains that a certain percentage did not undergo radiological imaging due to financial constraints, a common challenge in our low middle-income setting [36] [37]. Perhaps, this resonates with the call for validation of the use of biomarkers in the detection of mild TBI in the clinical setting as a cheaper option, as echoed by Papa and colleagues [38].

In this study, following CT scan imaging, most of the patients had skull fractures 65 (21.6%), followed by extracranial hemorrhage (16.6%), contusion (9.9%), and concussion (8.9%) among others. There was generally a low incidence of diffuse axonal injury and diffuse brain edema contrary to findings by Weber *et al*. [39]. These findings are in line with a study by Sarkar and colleagues who found that Pediatric patients with TBI were more likely to have skull fractures (OR 3.21, $p < 0.01$) and epidural hematomas (OR 1.96, $p < 0.01$). They further mentioned that pediatric TBI was less likely to be associated with contusion, subdural hematoma, subarachnoid hemorrhage, or compression of the basal cisterns ($p < 0.05$) [40]. They offered to explain that perhaps the differences may be related to anatomical characteristics, the biomechanics of injury, and/or differences in injury

mechanisms given the supple nature of pediatric brains, as compared to the adult population.

Furthermore, despite having a small number of patients with diffuse axonal injury in this study (14/193) (7.25%), Magnetic Resonance Imaging (MRI) was barely used for further evaluation mainly due to financial constraints, although its role in early management is arguable as mentioned by Janas and group [41] who found that high grades of DAI on early MRI (at 5 days) was associated with worse 6-month functional outcome and with discharge to inpatient rehabilitation in children with acute mild TBI. However, on further univariate analysis, it did not independently correlate with the outcome when controlling for the GCS score.

5.3. Treatment Outcomes and Public Measures

In this series, 89.7% of the children were managed conservatively, although a certain percentage (10.3%) got treated surgically, mostly due to skull fractures. The role of surgical management in skull fractures has been mentioned by Dewan *et al*. [42] with good outcomes.

The majority (52.9%) of children in this cohort were in the mild TBI (GCS 13-15) group on admission and perhaps this finding correlated with the favorable outcome across the cohort as it is well known in the literature that outcome is primarily dependent on the severity of PTBI at presentation [43]. 15.5% of the patients had neurological deficits and this could be attributed to inevitable sequela of secondary brain injury along with the presence of concomitant injuries; 24% had skeletal injuries, 12% had visceral injuries, and 0.5% polytrauma which could have impacted the overall clinical outcomes. The mortality rate in this series was relatively low at 4% (12/302) among the patients in the severe TBI group, comparatively similar to the KID study (4%) by Lu *et al*. [44].

In the one-month follow-up, more than half (55.6%) of the children were clinically stable; however, a few (9.6%) still had resolving neurological deficits and a mortality rate of 0.3%, reports largely similar to findings in the Malawi pediatric TBI series [45].

Regarding preventive public measures, several options have been laid down in different regions across the globe. Cassidy *et al*. emphasized that the strong evidence supports helmet use to prevent mild traumatic brain injury in motorcyclists and bicyclists [46].

In our earlier study in Nyamagana District, Mwanza, analyzing the perception of civilians on pre-hospital involvement in RTAs among the 151 participants, we found that emergency care before hospitalization was largely acceptable in terms of attitude, willingness with RTAs before hospitalization [47], a finding which could relate to early response and quicker referrals in this region. Chaitanya *et al*. in their pediatric series in India pointed out that most of these injuries are preventable in infancy and childhood by ensuring proper vigilance, and tender care by the parents and the caretakers [48]. Educational programs are much needed to address the gap in the mothers' KAP toward child injury prevention. Further stud-

ies are recommended to understand the cultural context and examine its key determinants to identify effective strategies and develop tailored interventions for preventing childhood injuries [49].

The need to increase training of neurosurgery-specific medical personnel has been echoed as one of the measures to mitigate this public burden locally by Kahamba *et al*. [50] and others [52].

In comparison to this 10-year report conducted at our institution [52], our institution has seen inevitable improvements in the scope of TBI management including 2 CT scan machines, MRI, >60-bed intensive care beds, and the recruitment of the associated personnel involved in the management of TBI. The recent enrolment of CT scans [24] in over 40 regional hospitals throughout Tanzania has seen a rapid increase in TBI referrals hence decreasing the rate of delayed referrals.

From an engineering perspective, a study by Jimoku *et al*. identifying the factors influencing the severity of motorcycle crashes found that speeding, driving under the influence, head-on impact, presence of horizontal curves, reckless riding, off-peak hours, violations, and riding without a helmet were among the influencing factors. They, hence, recommended countermeasures focusing on the fundamental highway safety improvement strategies comprising engineering, education, and traffic law enforcement [53].

6. Limitations of the Study

While utilizing the hospital-based information gathered from this study, it is important to bear in mind that this study was done only in a single tertiary hospital and thus was not representative of all other facilities within the region and furthermore could be a potential bias for noted increase in incidence in this study. Being a retrospective study, there are potential limitations including data loss in the hospital care from multiple providers and follow-up phase, during data input given dual English and Swahili speaking among patients, and contributing to a lack of generalizability of this study. The problem of missing information at admission and follow-up due to proper documentation among some patients could lead to a potential skew in the results.

7. Conclusion

In this single-center retrospective study, the annual incidence trends exponentially rose over 5-fold in three years with an annual incidence of 0.756 per 1000 cases per hospital admission. Children 1 - 3 years old were the most affected group, and Road Traffic Accidents (RTAs) were the most common cause of pediatric traumatic brain injury, similar to international reports. Efforts must be made to enhance awareness among parents and the public health system to foster more measures to mitigate this public burden.

Author Contributions

L. J. contributed to the conception and design of the study, acquired, analysed and

interpreted the data, and drafted and revised the manuscript. R. M., U. O. E., C. M. B. and L. J. contributed to the conception, design of the study, data interpretation and critically revised the manuscript. All authors read and approved the final manuscript.

Declaration of Generative AI in Scientific Writing

The authors disclose no use of AI and AI-assisted technologies in the writing process of the manuscript.

Ethical Considerations

Ethical clearance for conducting this research was sought from a joint Catholic University of Health and Allied Sciences/Bugando Medical Center (CUHAS/BMC) Research Committee (CREC).

Conflicts of Interest

Authors have nothing to declare.

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Abbreviations

AKI	Acute Kidney Disease
BMC	Bugando Medical Centre
CNS	Central Nervous System
DAI	Diffuse Axonal Injury
GCS	Glasgow Coma Scale
HICs	High Income Countries
LICs	Low Income Countries
LMICs	Low and Middle Income Countries
MICs	Middle Income Countries
MVA	Motor Vehicle Accidents
PTBI	Pediatric Traumatic Brain Injury