Prospective study of surgery for traumatic brain injury in Addis Ababa, Ethiopia: Trauma causes, injury types and clinical presentation.

Tsegazeab Laeke[1,2], Abenezer Tirsit[1,2], Azarias Kassahun[1], Abat Sahlu[1], Tequam Debebe[3], Betelehem Yesehak[1], Samuel Masresha[1], Negussie Deyassa[4], Bente E. Moen[5], Morten Lund-Johansen[2,6] and Terje Sundstrøm[2,6].

[1] Surgery Department, Neurosurgery Unit, Addis Ababa University, College of Health Sciences, Addis Ababa, Ethiopia.

[2] Department of Clinical Medicine, Faculty of Medicine, University of Bergen, Norway.
[3] Department of Radiology, Addis Ababa University, College of Health Sciences, Addis Ababa, Ethiopia

[4] School of Public Health, Addis Ababa University, College of Health Sciences, Addis Ababa, Ethiopia.

[5] Center for International Health, Department of Global Public Health and Primary Care, Faculty of Medicine, University of Bergen

[6] Department of Neurosurgery, Haukeland University Hospital, Bergen, Norway.

Running title: Traumatic brain injury in Ethiopia: Injuries.

Corresponding author: Tsegazeab Laeke, Surgery Department, Neurosurgery Unit, Addis Ababa University, College of Health Sciences, Ethiopia. Phone: +251 911437947. E-mail: tselaeke@gmail.com.

Key words: Traumatic brain injury, head injury, neurotrauma, epidemiology, low- and middle-income countries.

Manuscript word count: 2745 words.

Abstract word count: 249 words.

Abstract

Background: Traumatic brain injury (TBI) is a public health problem in Ethiopia. We need more knowledge about the epidemiology and neurosurgical management of TBI patients to identify possible focus areas for quality improvement and preventive efforts.

Methods: This was a prospective cross-sectional study (2012-2016) at the four teaching hospitals in Addis Ababa, Ethiopia. All surgically treated TBI patients were included, and details on clinical presentation, injury types and trauma causes were registered.

Results: We included 1087 patients (mean age 29 years; 8.7% females; 17.1% < 18 years of age). Only 15.5% of TBIs were classified as severe (Glasgow Coma Scale (GCS) score 3-8). Depressed skull fracture (DSF; 44.9%) and epidural hematoma (EDH; 39%) were the most frequent injuries. Very few patients were polytraumatized (3.1%). Assault was the most common injury mechanism (69.9%) followed by road traffic accidents (RTA; 15.8%) and falls (8.1%). More than 80% of patients came from within 200 kms of the hospitals, but the median time to admission was 24 hours. Most assault victims (80.4%) were injured more than 50 kms from the hospitals, whereas 46% of RTA victims came from the urban area. Delayed admission was associated with higher GCS scores and non-severe TBI ($p < 0.01$).

Conclusions: The injury panorama, delayed admission and few operations for severe TBI are linked to a substantial patient selection both before and after hospital admission. Our results also suggest that there should be a geographical framework for tailored guidelines, preventive efforts and development of prehospital and hospital services.

Introduction

According to recent global estimates, close to 90% of all trauma-related deaths occur in low- and middle-income countries (LMICs).[1] Neurologic injuries are the most important causes of death and disability from trauma, particularly in children and young adults.[2]

Studies on head and spinal injuries from LMICs are however underrepresented in the international literature.[3,4] Importantly, as different regions have their own needs and obstacles, neurotrauma research and management must be contextualized. It is not feasible to directly transfer cost-demanding, evidence-based guidelines from Western countries to LMICs, which lack the necessary finances, equipment and human resources. Thus, there is a great need for more and better data on epidemiological aspects and the entire continuum of care to facilitate development of locally tailored guidelines, improve quality of care, and identify region-specific focus areas for preventive efforts.[5,6]

Ethiopia is the second most populous country in Africa with about 115 million inhabitants.[7] Notably, it is a country of young people as 70% are under 30 years of age.[8] Ethiopia has one of the fastest growing economies in the world with a rapid rate of urbanization and industrialization, and has some of the highest numbers of road traffic injuries and deaths worldwide.[9,10] Fall accidents among construction workers are very common,[10] and there are high rates of injuries due to violence and assaults.[11,12] In studies from the emergency department (ED) at Black Lion Specialized Hospital in Addis Ababa, traumatic brain injury (TBI) was the leading cause of mortality and the most important indication for neurosurgical procedures.[13-15] The burden of trauma, especially neurotrauma, weighs heavily on the Ethiopian society,[11] and research that can lead to improved patient care and identify relevant focus areas for Ethiopian authorities is timely and highly warranted.

The Ethiopian/Norwegian training program in neurosurgery was started in 2006 and has been instrumental in developing a sustainable neurosurgical environment in Ethiopia.[16] A key issue for further development is research, particularly within the most prevalent disease conditions. To this end, we prospectively registered surgically treated TBI patients at the four teaching hospitals in Addis Ababa from 2012 to 2016. Herein, we describe the trauma causes, injury types and clinical presentation. In another paper, we report on the surgical treatment, complications and patient outcomes.[17]

Material and methods

Study setting

This study was done at the four neurosurgical teaching hospitals in Addis Ababa, Ethiopia: Black Lion Specialized Hospital, Myung Sung Christian Medical Center, Alert Hospital and Zewditu Memorial Hospital. These hospitals provide the majority of neurosurgical services in the country. Hospital management of TBI patients is based on the Advanced Trauma Life Support (ATLS) guidelines and the Brain Trauma Foundation guidelines.[18] More details on hospital management are described elsewhere.[17] This study is part of a larger collaborative research project approved by the Institutional Review Board (#003/16/surg), Addis Ababa

University, Ethiopia, and by the Regional Ethical Committee (#2018/53), University of Bergen, Norway.

Patients and data collection

In this prospective cross-sectional study, we included all TBI patients who were surgically treated from October 2012 to December 2016. Most patients were treated at Black Lion Specialized Hospital and Myung Sung Christian Medical Center. Alert Hospital and Zewditu Memorial Hospital started treating TBI patients in 2015 but were not fully operational before 2016. Most patients treated at Alert Hospital and Zewditu Memorial Hospital were transferred from Black Lion Specialized Hospital or Myung Sung Christian Medical Center. Alert Hospital and Zewditu Memorial Hospital did not receive direct transfers from district hospitals.

Neurosurgical residents recorded data from admission until discharge using a paper-based case report form (CRF). The CRF included data on demographics, injury mechanism, time of injury, computerized tomography (CT) findings, extracranial injuries, surgical procedures, complications, survival, and dates of admission, surgical procedures and discharge. The Glasgow Coma Scale (GCS) score was used to assess injury severity. TBIs were categorized as mild (GCS score 14-15), moderate (GCS score 9-13) and severe (GCS score 3-8).

Statistical analysis

Data was analyzed using SPSS version 21 (SPSS Inc., Chicago, IL, USA). The clinical status was used as the dependent variable and the effect of demographics, trauma mechanisms, geographical distance and time interval between trauma and admission were investigated by binomial and multinomial regression analysis. Unless otherwise specified, Chi-square test was used to test for association between categorical variables while T-test and Mann Whitney test were used for continuous variables. Missing data were checked for random distribution. A p-value < 0.05 was considered significant.

We analyzed predictors of severity categorized as severe (GCS score < 9) or not severe using multivariate analysis. Main diagnosis (depressed skull fracture (DSF), epidural hematoma (EDH), acute subdural hematoma (ASDH), penetrating brain injury (PBI) and traumatic intracerebral hematoma (tICH), miscellaneous), time to admission (cutoff 24 hours), trauma mechanism (assault, road traffic accident (RTA), fall, other), age (14-25, 26-35, 36-44 and above 44 years), sex, and distance from trauma site to hospital (cutoff 200 km) were categorized, and logistic regression was used for analysis. Finally, we included the abovementioned variables into a logistic regression model.

Results

Demographics and injury types

In the study period, 4412 TBI patients (90 patients from October to December 2012, 796 patients in 2013, 942 patients in 2014, 1284 patients in 2015 and 1300 patients in 2016) visited the ED of the four hospitals. A total of 1087 patients (24.6%) were surgically treated and included in this study. The mean age was 29 years and 91.3% were males (**Table 1**). Females were younger than males (mean age 24.7 vs. 29.4 years; $p = 0.01$). Among all patients, 17.1% were children (< 18 years). The sex distribution was less skewed among children than adults ($p < 0.01$).

The most common injury type was DSF (44.9%), followed by EDH, ASDH, PBI and tICH/contusion (**Table 1**). Among 1050 patients with registered TBI severity, 52.1% were mild, 29.1% were moderate and 15.5% were severe.

Polytrauma was infrequent with only 34 cases. The most common concomitant injuries were long bone fractures (24 patients) and chest injuries (six patients).

Mechanism of injury

The mechanism of injury was reported for 732 patients (**Table 1**). The most frequent cause of trauma was assault (69.9%) followed by RTAs (15.8%) and falls (8.1%). **Supplementary Table 1** shows a detailed overview of injury mechanisms according to the International Statistical Classification of Diseases and Related Health Problems, 10th revision (ICD-10).

Time to admission in hours was different for different injury mechanisms (Kruskal Wallis test; χ^2 (3) = 44.7, $p < 0.01$), with a mean rank in time to presentation of 243.4 for RTAs, 372.6 for assault, 322.3 for falls and 276.8 for other injuries (data not shown).

Assaults

There were 512 TBIs caused by assaults (**Table 1**). Assault was the most frequent cause of severe TBI (59%), but only 12.3% of 505 assault victims with documented TBI severity presented with a severe TBI (**Table 2**). The majority of assault victims (80.4%) came from outside of the city (**Figure 1**). Stick (50.4%) and thrown stone (21.6%) injuries were the most common types of assault (**Supplementary Table 1**). The most frequent injury types were DSF (45.3%), EDH (38.1%) and PBI (12.5%) (**Table 3**). Assault victims more often presented with a DSF or PBI than patients suffering other injury mechanisms (**Table 3**). Gunshot injuries were present in 42 patients and six of these were classified as severe TBIs (**Supplementary Table 1**).

Road traffic accidents

There were 116 cases of traffic-related TBI (**Table 1**). Injury severity was documented in 112 patients, and 19.8% of these patients had a severe TBI (**Table 2**). Pedestrians accounted for 71.3% of cases **(Supplementary Table 1)**. Victims of RTAs were frequently brought in from within 50 kms of the hospitals (45.9%; **Figure 1**) and were admitted earlier than other patients ($p < 0.01$; **Supplementary Table 1**). EDH and DSF were the most frequent pathologies caused by RTAs (**Table 3**). EDH and ASDH were more common among RTA victims, whereas DSF was 65% less frequent in RTAs compared to assaults (**Table 4**).

Falls

A severe TBI occurred in 23.7% of 59 fall accidents (**Table 1 and 2**). Falls from ladders, buildings, stairs or scaffolding accounted for 42.4% of cases (**Supplementary Table 1**). EDH and DSF were the most common (86.4%) injuries caused by falls (**Table 3**).

Miscellaneous

Other trauma mechanisms were encountered in 45 cases (**Table 1**). Injury severity was documented in 44 cases, of which 15.9% were severe (**Table 2**). Most of these injuries were related to animals, caused by falling objects or sport activities (**Supplementary Table 1**). Severe TBIs were typically seen in elderly farmers who were gored, kicked or stamped on by their cattle. DSF and EDH were the most frequent (80%) injury types (**Table 3**).

Distance from hospital and time to admission

Distance from the accident scene to the hospitals was recorded for 1045 patients (**Table 1**). Most patients (81.7%) were injured less than 200 km from the hospitals, i.e. they came from Addis Ababa or neighboring areas (**Table 1 and Figure 1**).

Time from injury to admission was registered for 705 patients (**Table 1**). The median time from injury to admission was 24 hours, and time to admission was strongly related to the distance from the hospitals ($p < 0.01$). There was a statistically significant difference in admission GCS score between the different categories of time to admission ($p < 0.01$) (**Table 5**). Patients who presented within six hours of injury had the lowest mean GCS score (11.22) and those who presented more than 120 hours after injury had the highest GCS score (14.04).

Predictors of severity

In bivariate analysis, we found a lower risk of severe TBI with DSF ($p < 0.01$) or assault ($p = 0.04$) as compared to other diagnoses or injury mechanisms. Patients with long transportation times were also less likely to present with a severe TBI ($p < 0.01$). Sex, distance from hospital and age were not significantly associated with severity.

Using DSF and assault as references for diagnosis and mechanism, respectively, we included the above variables into a logistic regression model to analyze predictors of severe TBI (**Table 6**). EDH (OR = 13.5), ASDH (OR = 26.3) and falls (OR = 2.8) were significant predictors of a severe injury. A long transportation time was significantly associated with non-severe injuries (OR = 0.3).

Discussion

In this study, we present novel data on surgically treated TBI patients in Ethiopia. Most patients were adolescent or young adult males with a mean age below 30 years. DSF and EDH were the most frequent (>80%) injury types, and the majority of patients (>50%) had a GCS score of 14-15 at presentation. Approximately 70% of TBI patients were injured in assaults. Hospital admission was often delayed with a median time to admission of 24 hours. Delayed admission was associated with a non-severe TBI, and vice versa.

Most patients in our study came from outside of Addis Ababa, and we found a longer time to admission than reported in other studies.[4,12,19] Long transportation times were significantly associated with better GCS scores. Importantly, there are usually no prehospital services and patients are typically taken to hospital in private cars or taxis.[20] Ambulance transports are usually reserved for interhospital transfers because of missing neurosurgical services or CT scanners at district hospitals, and ambulances are usually not staffed with paramedics.[3] Thus, there is a selection where severely injured patients at distant sites die before reaching the neurosurgical center, either at the site, during transport or at district hospitals. This is clearly indicated by the positive correlation between injury severity (i.e., GCS score) and time to admission, as well as the low numbers of ASDH, PBI and tICH/contusion, usually associated with a higher injury severity. Moreover, there is also a selection at the neurosurgical centers where patients in poor condition are not operated. Intensive care unit (ICU) admission and surgical treatment is usually prioritized for patients with a GCS score of 5 or more and normal pupillary responses, as it is believed these patients have a better prognosis. Notably, a study from Black Lion Specialized Hospital in Addis Ababa showed 50.8% mortality of severe TBI in the ED, and 62% of the survivors were operated.[3]

The predominance of males and young patients as well as the infrequency of injured children has been reported previously.[21-23,24,25] The high proportion of assaults is distinctive from many studies from both developed and developing countries,[26,27] but reflects a selection of less injured patients for surgery. Non-RTA associated TBI, such as assault, was also found significantly associated with receiving surgery in recent studies from referral hospitals in Uganda[28] and Tanzania.[29] Most of the registered assaults in our study took place in rural areas outside of Addis Ababa; interestingly, this has also been noted in other reports comparing rural and urban areas.[23,30] Stick injuries were the most frequent assault types. Notably, close to 80% of the Ethiopian population live in rural areas, and it is here very common to carry sticks for self-defense and for support during long hours of work and commuting.[31] Interestingly, stick injuries are frequently seen on the left side of the head as most people are right-handed. Sticks cause a focal low-energy trauma to the head, which is less likely to result in severe depression of consciousness.[32] Assault victims therefore typically present with a high GCS score, and CT findings of DSF and/or EDH. In a comparable study, Peeters and colleagues reported similar findings of frequent DSFs.[33]

Motorization and urbanization are rapidly developing in the sub-Saharan region and RTAs are increasing.[4,21,26] In our study, RTAs were the second most frequent cause of TBI. As previously reported from LMICs [6,22,34], we found that most RTAs involved pedestrians. Pedestrians were also brought in earlier than vehicle occupants, usually in the offending vehicle, whereas car occupants have to wait for transportation. As opposed to assaults, patients admitted after RTAs were more frequently from urban areas. This indicates a geographical distribution of vehicle density, but also a selection of less severe injuries, as discussed above.

Fall accidents were the third most common cause of TBI. The number of fall accidents would probably have been higher if we included those that died on the scene of the accident and those who were treated non-surgically. Work-related falls were most frequent in our study and are associated with many large-scale construction projects in the city and poor precautionary measures. This contrasts the changing epidemiologic panorama of HICs, where there is an increasing incidence of fall-related TBIs among the elderly.[34]

In our study, 1087 (24.6%) patients were operated for a TBI over a 4-year period out of 4412 TBI patients who presented to the ED of our four hospitals. Only two hospitals in Addis Ababa were operational the entire study period, and there was approximately one neurosurgeon per four million inhabitants.[16] Surgical activity is increasing year by year, and more than 2000 neurosurgical procedures are now performed every year. In a recent study from the main tertiary hospital in Uganda looking at all admitted TBI patients in the period 2014-2015, only 242 (19%) of 1247 patients were operated.[28] In a similar study from a referral hospital in Tanzania of 2502 TBI patients admitted in the period 2013-2017, only 609 (24%) received surgery.[29] Taken together, although relatively few patients undergo surgery, the latter study showed a variable but clear benefit of surgery for all TBI severities, providing a clear rationale for further development of neurosurgical services in Sub-Saharan Africa.

Conclusions

TBI is a major public health problem in Ethiopia and our novel data on neurosurgical management of TBI can help to improve the quality of care and identify focus areas for preventive efforts. Many young patients die or experience significant treatment delay because of limitations within prehospital services and local hospitals, and efforts should be made to counter this development (e.g., trauma resource allocation, ambulance services, systematic referral systems from district hospitals, telemedicine programs, increased CT accessibility, neurosurgical education and outreach programs).[35-37] Furthermore, as more patients survive acute TBI surgery, rehabilitation should become a more integral part of the treatment.

Many of these issues are not unique to the neurosurgical domain and can be addressed by more resources or better use of the resources at hand. Moving ahead, prioritizations and solutions should be discussed between local and governmental officials, health care leaders and medical experts. Public awareness campaigns, safety standards and legislative measures could further help to reduce the detrimental consequences of TBI in Ethiopia. Specifically, there should be prevention strategies against stick injuries, and natural considerations should be to ban the use of sticks in public places or awareness campaigns about the detrimental consequences of stick injuries.

References

1. World Health Organization. Global Burden of Disease (GBD). 2010; http://www.who.int/healthinfo/global_burden_disease/gbd/en/.
2. Rubiano AM, Carney N, Chesnut R, Puyana JC. Global neurotrauma research challenges and opportunities. *Nature.* 2015;527(7578):S193-197.
3. Laeke T, Tirsit A, Debebe F, et al. Profile of Head Injuries: Pre hospital Care, Diagnosis and Severity in an Ethiopian Tertiary Hospital. *World neurosurgery.* 2019.
4. Eaton J, Hanif AB, Grudziak J, Charles A. Epidemiology, Management, and Functional Outcomes of Traumatic Brain Injury in Sub-Saharan Africa. *World neurosurgery.* 2017;108:650-655.
5. Rubiano AM, Puyana JC, Mock CN, Bullock MR, Adelson PD. Strengthening neurotrauma care systems in low and middle income countries. *Brain injury.* 2013;27(3):262-272.
6. Qureshi JS, Ohm R, Rajala H, et al. Head injury triage in a sub Saharan African urban population. *Int J Surg.* 2013;11(3):265-269.
7. Dynamics UNDoEaSAP. UN World Population Prospects. 2019; https://population.un.org/wpp/Maps/. Accessed 05/05/2020, 2020.
8. Ethiopia Central Statistical Agency E. Mini Demographic and Health Survey 2014. *Ethiopia Central Statistical Agency Bulletin.* 2014.
9. World Health Organization. Global status report on road safety: time for action. 2009.
10. Tadesse S, Israel D. Occupational injuries among building construction workers in Addis Ababa, Ethiopia. *J Occup Med Toxicol.* 2016;11:16.
11. A Aklilu SN, N birhanou. Trauma in Ethiopia Revisited: A systematic Review. *East Cent Afr J surg.* 2013;18.
12. Gomez PA, Castano-Leon AM, de-la-Cruz J, Lora D, Lagares A. Trends in epidemiological and clinical characteristics in severe traumatic brain injury: Analysis of the past 25 years of a single centre data base. *Neurocirugia (Asturias, Spain).* 2014;25(5):199-210.
13. H Cheryl TS, M Nazanin,M Christopher,PR Lisa. Patterns and predictors of early mortality among emergency department patients in Addis Ababa,Ethiopia. *BMC Res Notes.* 2015;8.
14. EE. Solano YOM, M Seyoum K. A one-year retrospective study on the pattern of death found at autopsy at Forensic Pathology Department, Menelik II Hospital in Addis Ababa, Ethiopia. *East and Central African Journal of Surgery.* 2017;22.
15. Mersha Abebe GL, Abebe Bekele. Pattern of Neurosurgical Procedures in Ethiopia: Experience from Two Major Neurosurgical Centres in Addis Ababa. *East and Central African Journal of Surgery.* 2011.
16. Lund-Johansen M, Laeke T, Tirsit A, et al. An Ethiopian Training Program in Neurosurgery with Norwegian Support. *World neurosurgery.* 2017;99:403-408.

17. Laeke T, Tirsit A, Kassahun A, et al. Prospective study of surgery for traumatic brain injury in Addis Ababa, Ethiopia: Surgical procedures, complications and postoperative outcomes. 2020.
18. Nancy Carney AMT, Cindy O'Reilly, Jamie S. Ullman,Gregory W.J. Hawryluk,Michael J. Bell,Susan L. Bratton,Randall Chesnut,Odette A. Harris, Niranjan Kissoon,Andres M. Rubiano,Lori Shutter, Robert C. Tasker,Monica S. Vavilala,Jack Wilberger,. Guidelines for the Management of Severe Traumatic Brain Injury. 4th ed2016. Accessed 29/1/2020.
19. Malomo TA, Oyemolade TA, Adeleye AO. Determinants of Timing of Presentation of Neurotrauma Patients to a Neurosurgical Center in a Developing Country. *Journal of neurosciences in rural practice.* 2018;9(4):545-550.
20. Meskere Y, Dinberu MT, Azazh A. PATTERNS AND DETERMINANTS OF PRE-HOSPITAL CARE AMONG TRAUMA PATIENTS TREATED IN TIKUR ANBESSA SPECIALIZED HOSPITAL, EMERGENCY DEPARTMENT. *Ethiop Med J.* 2015;53(3):141-149.
21. Hyder AA, Wunderlich CA, Puvanachandra P, Gururaj G, Kobusingye OC. The impact of traumatic brain injuries: a global perspective. *NeuroRehabilitation.* 2007;22(5):341-353.
22. Kuo BJ, Vaca SD, Vissoci JRN, et al. A prospective neurosurgical registry evaluating the clinical care of traumatic brain injury patients presenting to Mulago National Referral Hospital in Uganda. *PLoS One.* 2017;12(10):e0182285.
23. Nell V, Brown DS. Epidemiology of traumatic brain injury in Johannesburg--II. Morbidity, mortality and etiology. *Social science & medicine (1982).* 1991;33(3):289-296.
24. Udoh DO, Adeyemo AA. Traumatic brain injuries in children: A hospital-based study in Nigeria. *African journal of paediatric surgery : AJPS.* 2013;10(2):154-159.
25. Lalloo R, van As AB. Profile of children with head injuries treated at the trauma unit of Red Cross War Memorial Children's Hospital, 1991 - 2001. *South African medical journal = Suid-Afrikaanse tydskrif vir geneeskunde.* 2004;94(7):544-546.
26. Sitsapesan HA, Lawrence TP, Sweasey C, Wester K. Neurotrauma outside the high-income setting: a review of audit and data-collection strategies. *World neurosurgery.* 2013;79(3-4):568-575.
27. Tagliaferri F, Compagnone C, Korsic M, Servadei F, Kraus J. A systematic review of brain injury epidemiology in Europe. *Acta neurochirurgica.* 2006;148(3):255-268; discussion 268.
28. Jin MC, Kakusa B, Ku S, et al. Long-term follow-up of neurosurgical outcomes for adult patients in Uganda with traumatic brain injury. *J Neurosurg.* 2020:1-11.
29. Elahi C, Rocha TAH, da Silva NC, et al. An evaluation of outcomes in patients with traumatic brain injury at a referral hospital in Tanzania: evidence from a survival analysis. *Neurosurgical focus.* 2019;47(5):E6.
30. Maier D, Njoku I, Jr., Schmutzhard E, et al. Traumatic brain injury in a rural and an urban Tanzanian hospital--a comparative, retrospective analysis based on computed tomography. *World neurosurgery.* 2014;81(3-4):478-482.
31. economy.com Tg. Ethiopia: Rural population, percent. *Business and economic data for 200 countries* 2019; https://www.theglobaleconomy.com/Ethiopia/rural_population_percent/.
32. Chattopadhyay S, Tripathi C. Skull fracture and haemorrhage pattern among fatal and nonfatal head injury assault victims - a critical analysis. *Journal of injury & violence research.* 2010;2(2):99-103.
33. Peeters S, Blaine C, Vycheth I, Nang S, Vuthy D, Park KB. Epidemiology of Traumatic Brain Injuries at a Major Government Hospital in Cambodia. *World neurosurgery.* 2017;97:580-589.
34. Roozenbeek B, Maas AI, Menon DK. Changing patterns in the epidemiology of traumatic brain injury. *Nature reviews Neurology.* 2013;9(4):231-236.
35. Olldashi F, Latifi R, Parsikia A, et al. Telemedicine for Neurotrauma Prevents Unnecessary Transfers: An Update from a Nationwide Program in Albania and Analysis of 590 Patients. *World neurosurgery.* 2019;128:e340-e346.
36. Sagaro GG, Battineni G, Amenta F. Barriers to Sustainable Telemedicine Implementation in Ethiopia: A Systematic Review. *Telemedicine Reports.* 2020;1(1):8-15.

37. Nakahara S, Saint S, Sann S, et al. Exploring referral systems for injured patients in low-income countries: a case study from Cambodia. *Health Policy and Planning.* 2009;25(4):319-327.

	N (%)
All	1087
Males	992 (91.3)
Age, mean (SD)	29.0 (14.7)
<18 years of age	186 (17.1)
Head injury types	1087
DSF	488 (44.9)
EDH	424 (39.0)
ASDH	76 (7.0)
PBI	74 (6.8)
tICH/contusion	23 (2.1)
Other	2 (0.2)
Polytrauma	34 (3.1)
Severity	1050
Mild	566 (52.1)
Moderate	316 (29.1)
Severe	168 (15.5)
Injury mechanism	732
Assault	512 (69.9)
RTA	116 (15.8)
Fall	59 (8.1)
Other	45 (6.1)
Distance to hospital	1045
<200 kms	854 (81.7)
Time to admission	705
Hours, median (IQR)	24.0 (60)

Table 1. Demographics, injury characteristics, trauma mechanisms and transport details. Unless otherwise indicated, the provided values are counts with percentages in brackets. Abbreviations: Depressed skull fracture (DSF), epidural hematoma (EDH), acute subdural hematoma (ASDH), penetrating brain injury (PBI), traumatic intracerebral hematoma (tICH) and road traffic accident (RTA).

	RTA	Assault	Fall	Other

Severe	22 (21.0)	62 (59.0)	14 (13.3)	7 (6.7)
Moderate	32 (15.5)	148 (71.5)	12 (5.8)	15 (7.2)
Mild	58 (14.2)	295 (72.3)	33 (8.1)	22 (5.4)

Table 2. Head injury severity and mechanism of injury for 720 patients, N (%). Severe (GCS score 3-8), moderate (GCS score 9-13) and mild (GCS score 14-15). Abbreviation: Road traffic accident (RTA).

	RTA	**Assault**	**Fall**	**Other**
DSF	33 (10.6)	232 (74.6)	25 (8.0)	21 (6.8)
EDH	65 (21.6)	195 (64.8)	26 (8.6)	15 (5.0)
ASDH	14 (32.6)	16 (37.2)	6 (14.0)	7 (16.3)
PBI	1 (1.5)	64 (97.0)	0	1 (1.5)
tICH/contusion	2 (20.0)	5 (50.0)	2 (20.0)	1 (10.0)
Other	1 (100)	0	0	0

Table 3. Main diagnosis and injury mechanism for 732 patients, N (%). Abbreviations: Depressed skull fracture (DSF), epidural hematoma (EDH), acute subdural hematoma (ASDH), penetrating brain injury (PBI), traumatic intracerebral hematoma (tICH) and road traffic accident (RTA).

		Yes (N, %)	**No (N, %)**	**OR (95% CI)**
DSF	Assault	293 (57.2)	219 (42.8)	1.00
	RTA	37 (31.9)	79 (68.1)	0.35 (0.23,0.54)
	Fall	27 (45.8)	32 (54.7)	0.63 (0.37,1.10)

	Other	25 (55.6)	20 (44.4)	0.93 (0.51,1.72)
ASDH	Assault	18 (3.5)	494 (96.5)	1.00
	RTA	15 (12.9)	101 (87.1)	4.1 (2.0,8.4)
	Fall	6 (10.2)	53 (89.8)	3.1 (1.2,8.2)
	Other	7 (15.6)	38 (84.4)	5.1 (2.0,12.9)
EDH	Assault	203 (39.6)	309 (60.4)	1.00
	RTA	64 (55.2)	52 (44.8)	1.9 (1.25,2.81)
	Fall	26 (44.1)	33 (55.9)	1.2 (0.70,2.10)
	Other	16 (35.6)	29 (64.4)	0.84 (0.45,1.60)

Table 4. Logistic regression analysis of injury type and injury mechanism. Abbreviations: Depressed skull fracture (DSF), acute subdural hematoma (ASDH), epidural hematoma (EDH), and road traffic accident (RTA). Odds ratio (OR) with 95% confidence interval (CI).

Time to admission (hrs)	Mean GCS score ± SD	N = 693
<6	11.22 ± 3.7	85
6-12	11.05 ± 3.9	74
12-24	11.67 ± 3.7	189
24-72	12.77 ± 3.0	175
72-120	13.05 ± 2.7	87
>120	14.04 ± 2.1	83

Table 5. GCS scores for 693 patients with categorized time to admission. The mean GCS score ± standard deviation (SD) is provided.

		df	Sig.	Exp (B)	95% C.I.	
					Upper	Lower
Diagnosis	DSF (ref.)					
	EDH	1	0.000	13.5	4.951	28.346
	ASDH	1	0.000	26.3	6.421	52.258
	PBI	1	0.001	6.7	1.967	19.293
	tICH	1	0.002	21.5	2.718	135.504

Injury mechanism				N=754	Time to admission; median hrs (IQR)	Age; mean years (SD)
Injury mechanism	Assault (ref.)					
	RTA	1	0.972	1.0	0.53	1.93
	Fall	1	0.012	2.8	1.25	6.24
	Other	1	0.655	0.8	0.27	2.3
	>24 hrs	1	0.000	0.344	0.203	0.584
	>200 kms	1	0.25	0.68	0.355	1.307
Age groups	18-44 yrs (ref.)					
	45-65 yrs	1	0.78	1.15	0.43	3.05
	>65 yrs	1	0.25	1.9	0.64	5.55
	0-17 yrs	1	0.38	0.35	0.034	3.64

Table 6. Multivariate regression analysis of predictors of injury severity. Abbreviations: Depressed skull fracture (DSF), epidural hematoma (EDH), acute subdural hematoma (ASDH), penetrating brain injury (PBI), traumatic intracerebral hematoma (tICH) and road traffic accident (RTA).

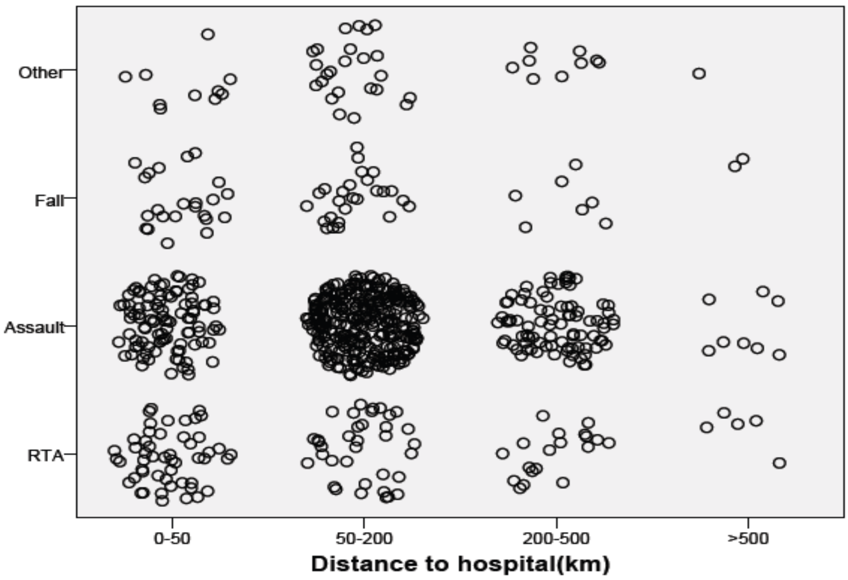

Figure 1. **Geographical distribution of injury mechanisms for 712 patients with complete data. Individual patients are indicated by circles. Abbreviation: Road traffic accident (RTA).**

Assault	**504**	**48.0 (78)**	**29.5 (11.7)**
Stick injury (Y00)	254 (50.4)		
Hit by a sharp object (X99)	89 (17.7)		
Hit by a thrown stone (W20)	109 (21.6)		
Punched	1 (0.2)		
Assault by hanging, strangulation & suffocation (X91)	8 (1.6)		
Assault by rifle or shotgun (X94)	42 (8.3)		
Blast injury (X96)	1 (0.2)		
Road traffic accident	**115**	**12.0 (43)**	**28.7 (15.6)**
Pedestrian ran over by 2/3-wheeled vehicle (V02)	10 (8.7)		
Pedestrian ran over by a car (V03)	72 (62.6)		
Occupant of 3-wheeled motor vehicle injured in transport accident (V30-V39)	5 (4.3)		
Car occupant injured in transport accident (V40-V49)	22 (19.1)		
Injured riding a motorcycle (V20-V29)	6 (5.2)		
Fall	**59**	**24.0 (84)**	**29.4 (20.3)**
Fall from stairs (W10)	4 (6.8)		
Fall from ladder (W11)	1 (1.7)		
Fall from, out of or through building or structure (W13)	11 (18.6)		
Fall from scaffolding (W12)	9 (15.3)		
Fall from tree (W14)	12 (20.3)		
Fall from cliff (W15)	7 (11.9)		
Fall from standing position (W01)	11 (18.6)		
Fall pediatrics	3 (5.1)		
Fall from a stationary car (V58.2)	1 (1.7)		
Animal-related injuries	**22**	**24.0 (39)**	**39.3 (21.7)**
Horse kick	9 (40.9)		
Attacked by cattle	2 (9.1)		
Fall from horse	11 (50)		
Sports injury	1		
Trivial trauma	5		
Hit by falling object	17		
Unknown mechanism	31		

Supplementary Table 1: Injury mechanisms categorized according to the ICD-10 classification of 754 patients with registered information about injury mechanisms (https://icd.who.int/browse10/2016/en#/V20-V29).