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Prehospital Conditions and Outcomes After Craniotomy for Traumatic Brain Injury Performed Within 72 Hours in Central Cameroon: A Cross-Sectional Study

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■ BACKGROUND: Traumatic brain injury (TBI) is the most common neurosurgical condition globally. In Cameroon, there are 572 cases of TBI per 100,000 people, but <40% of Cameroonians live within 4 hours of a neurosurgical facility. We sought to understand the clinical outcomes at a neurosurgical center in Central Cameroon.

■ METHODS: This cross-sectional study was conducted at the largest neurosurgical center of Cameroon, the Yaounde Central Hospital. Data included 100 consecutive patients undergoing an intervention 72 hours after their injury from February 1, 2015 to February 1, 2019. Patients with missing data or undergoing surgery >72 hours after injury were excluded. Analyses of covariance were performed, and a *P* value >0.05 was considered significant. A Kaplan-Meier survival curve was computed.

■ RESULTS: The patients had a mean age of 31.3 ± 17.4 years, with a male predominance of 91.0%, and the principal mechanism of injury was road traffic accidents (68.0%). Only 11% arrived via ambulance, and 36.0% were admitted <3 hours after the traumatic event. The postoperative mortality was 15.0%, mean survival was 25.0 postoperative days (95% confidence interval, 23.42–26.52), and the mean Glasgow Outcome Scale score at 28 days was 3.9 ± 1.4 .

■ CONCLUSIONS: Most patients with TBI undergoing neurosurgery 72 hours after injury in Cameroon arrive at the hospital late and have a high mortality risk during the first postoperative week. Investments in prehospital care should be made to improve surgical outcomes.

INTRODUCTION

The World Health Organization has identified traumatic brain injury (TBI) as a global public health issue.¹ The global burden of TBI has increased by 8.0% in 25 years, leading to 8 million years lost to disability and 27 million new cases of TBI annually.² This increase has been attributed to urbanization, poor road networks, deficient traffic law enforcement, and underresourced public health systems in low- and middle-income countries (LMICs).^{3–6} LMICs account for 72.4% of all TBI cases, yet they have the smallest neurosurgical workforce density.^{6,7} Cameroon is a Central African country that is directly affected by these challenges.

There are 572 cases of TBI per 100,000 people in Cameroon, primarily affecting adult males involved in road traffic accidents (RTAs).^{2,5,8,9} In most Cameroonian cities, motorcycles are a popular means of transportation. Motorcycles have the advantage of being affordable and efficient and permit local

Key words

- Cameroon
- Craniectomy
- Cranioplasty
- Craniotomy
- Global neurosurgery
- Neurosurgery
- Neurotrauma
- Traumatic brain injury

Abbreviations and Acronyms

aSDH: Acute subdural hematoma

EDH: Extradural hematoma

GCS: Glasgow Coma Scale

GOS: Glasgow Outcome Scale

HICs: High-income countries

LMICs: Low- and middle-income countries

RTA: Road traffic accident

TBI: Traumatic brain injury

WFNS: World Federation of Neurosurgical Societies

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transportation from bus stops to the individual's final destination. However, helmet use is low, speed limits are not enforced, and roads are derelict.^{3,9,10} Riders and passengers are therefore exposed to higher risks, and more severe TBI after RTAs.⁹ Deficient prehospital care and referral systems also result in barriers to reaching care; few patients arrive at definitive care facilities within the TBI golden hours, which are believed to be arrival at a center capable of neurosurgical intervention within 4 hours of the trauma.^{6,10–12} There is an 8.0% increase in the number of people with a Glasgow Outcome Scale (GOS) score ≤ 3 in patients admitted >4 hours after the initial injury.¹² Only 36.0% of Cameroonians live within 4 hours of a neurosurgical facility, and the neurosurgical density is low at just 1 neurosurgeon per 1 million population.^{13–15} All these factors contribute to the compounded burden of TBI within Cameroon.

Given the large estimated burden of neurotrauma in Cameroon, the purpose of this study is to describe intervention types, clinical outcomes, and practice variation at the largest neurosurgical center in Cameroon. To our knowledge, this is the first in-depth study of neurosurgical trauma interventions and clinical outcomes in the central region of Cameroon.

METHODS

This cross-sectional study was carried out within the neurosurgery departments of the Central Hospital of Yaounde. The Central Hospital of Yaounde, the country's largest and busiest trauma center, is a 650-bed facility located in the capital city Yaounde.¹⁶ It is a World Federation of Neurosurgical Societies (WFNS) level 3 neurosurgical center, which is staffed by 4 neurosurgeons and 12 nurses and receives referrals from throughout the country.¹⁷

Data were collected retrospectively from patient medical records, and all discharged patients were contacted via telephone to obtain access to their imaging. We reviewed emergency department admissions records and operative records from February 1, 2015 to February 1, 2019. There is often a delay between injury, reaching care, the decision to operate, and the surgical intervention.¹⁸ In-hospital delays often result from financial barriers and a lack of emergency services coverage. Of Cameroonians, 82.0% pay for neurosurgical health care expenses out of pocket.¹⁹ The 72-hour postinjury cutoff was based on local expert opinion and reports that show that emergency neurosurgery for trauma beyond 72 hours correlates with adverse outcomes.²⁰ Therefore, all patients who underwent surgery within 72 hours for TBI were included. Patients with missing medical records, incomplete medical records, or who were operated on >72 hours after the head injury were excluded. The time from injury to admission recorded as 3-hour ranges was extracted from patient records. The time of injury had been obtained from patients when possible, and from witnesses when the patients were unconscious or did not remember. Patient records were equally reviewed for radiologic diagnosis. Data were extracted from the radiology report when available; when unavailable, scans were interpreted by a neurosurgical consultant (B.F.). Institutional review board approval was obtained from the Central Hospital of Yaounde before data collection.

Statistical Methods

Statistical analyses were performed using SPSS version 26 (IBM Corp., Armonk, New York, USA). Age, Glasgow Coma Scale (GCS) score, GOS score, length of stay, and postoperative day of death were analyzed as continuous variables. Patient characteristics were summarized as means and standard deviations for continuous variables, whereas categorical variables were summarized as counts and percentages. The strengths of associations were measured, and analysis of covariance was used to correct for confounding. Patient survival was analyzed using Kaplan-Meier analysis. We set the threshold of significance at 0.05.

RESULTS

Patient Demographics

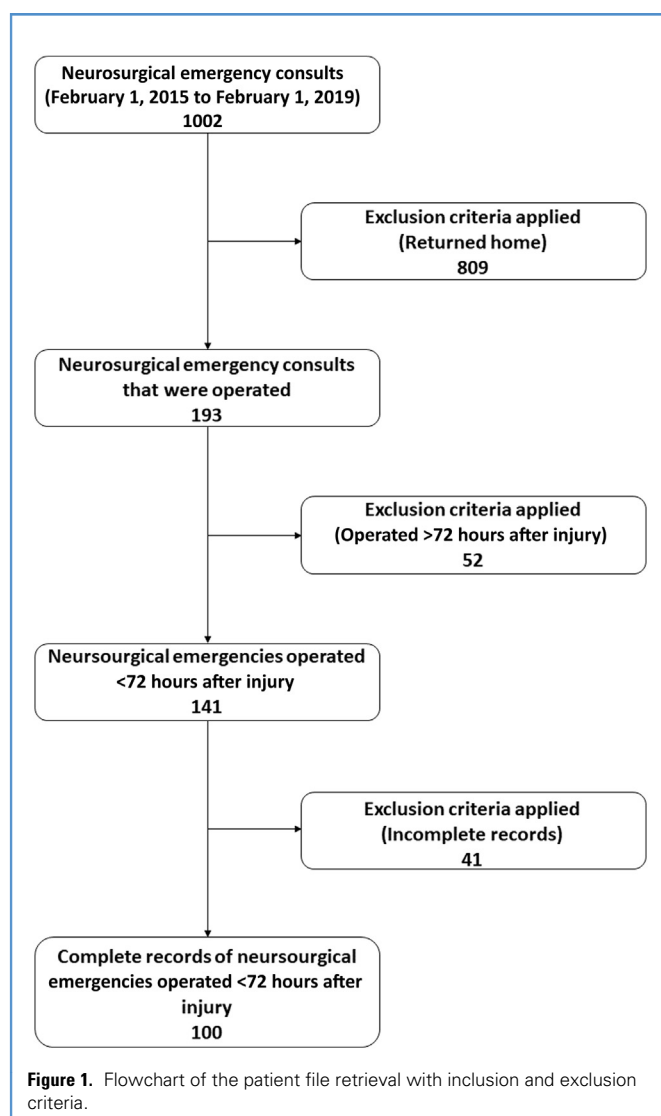
We identified 1002 patient admissions for TBI from February 1, 2015 to February 1, 2019 (Figure 1). A total of 141 underwent surgery within 72 hours after injury. However, 41 were excluded from analysis because of incomplete records.

One hundred patients were included: aged 1–78 years (mean, 31.3 ± 17.4 years) with a male predominance (91.0%) (Table 1). The principal mechanism of injury was RTAs (68.0%) followed by physical aggression (23.0%) and falls (9.0%). Of the patients who had RTAs, 79.4% were either pedestrians or riding motorcycles at the time of injury. Only 11 patients (11.0%) arrived via ambulance, and these were all referrals. Thirty-six patients (36.0%) were admitted to the neurosurgery department within 3 hours of their injury, whereas most (59.0%) were admitted beyond the 6-hour mark. Fifty-one of the 59 patients (86.0%) admitted >6 hours after the accident were referrals. Referrals accounted for 54.0% of all 100 admissions, and three quarters of all referrals (75.9%; $n = 41$) were from district-level hospitals or lower.

Clinical Presentation

Most patients admitted (51.0%) had a GCS score of 14–15, whereas 26.0% of patients had a GCS score ≤ 8 . Sixty-seven patients lost consciousness at the time of the accident, and only 7 (10.4%) of them reported experiencing a lucid interval. Nine patients had epistaxis (9.0%), 7 had otorrhagia (7.0%), and 5 had both epistaxis and otorrhagia (5.0%). Almost a quarter of all patients (23.0%) had sustained injuries to another body system. Because of a lack of equipment, it was not possible to measure the intracranial pressure invasively or noninvasively.

Noncontrast computed tomography scans showed extradural hematomas (EDHs) (41.0%), depressed skull fractures (33.0%), acute subdural hematomas (aSDHs) (22.0%), cerebral contusions (16.0%), traumatic intraparenchymal hemorrhage (2.0%), and combined EDH and aSDH (2.0%). Most EDH (75.0%; $n = 33$) were temporal or parietal, 6 were bilateral (13.6%; $n = 6$), and 39 had a volume >30 cm³ (88.6%) and a thickness >15 mm. Most patients presenting with severe trauma had EDH (42.3%), a pupillary anomaly (58.3% with an anisocoria and 87.7% with bilateral mydriasis), almost uniformly associated with herniation (78.6%). Regarding patients with aSDH, hematoma volume exceeded 5 mm³ in 95.8% of cases ($n = 23$), and 2 aSDHs were bilateral (8.3%; $n = 2$); neurologic deficits were frequent (42.9%), and a notion of the initial loss of consciousness was present in 83.3% ($n = 24$).



Patients were operated on within 72 hours of their injury based on clinical and radiologic findings. All patients received antibiotics perioperatively, and every patient with depressed skull fractures received prophylactic antiepileptic drugs. Craniotomies were performed using Hudson braces and Gigli saws. Burr holes were made into the skull and then were connected with a Gigli saw. The Gigli saw was inserted with a guide to avoid inadvertent dural tears. When the patient had depressed fractures of the cranial vault, the fracture fragments were elevated and debrided. EDHs were evacuated with curettes. Bone wax, bipolar electrocautery, and absorbable hemostat were used for hemostasis. Then, the dura mater was suspended to the galea, the bone flap was replaced, and the scalp was closed under a nonaspirating drain. Twelve patients (12.0%) had craniotomies, 42 (42.0%) had craniectomies with subsequent cranioplasty, and 46 (46.0%) had elevation and debridement of cranial vault fragments. Of patients, 95.0% underwent control computed tomography of the head.

Clinical Outcomes

The GOS score at postoperative day 28 was significantly associated with age ($P = 0.001$), GCS score ($P = 0.000$), pupillary anomaly ($P = 0.007$), and subdural hematoma ($P = 0.038$) (Table 2). There was a significant difference in the mean GOS score at postoperative day 28 between the ages [$F_{1,94} = 11.356$; $P = 0.001$], pupil sizes [$F_{1,94} = 6.219$; $P = 0.014$], and the existence of a subdural hematoma [$F_{1,94} = 5.407$; $P = 0.022$] when adjusting for GCS score. We registered 15 deaths (15.0%), all occurring during hospital admission.

The mean GOS score on postoperative day 28 was 3.9 (standard deviation = 1.4), and 12 patients were lost to follow-up (12.0%). Twelve patients (80.0%; $n = 12$) with a GOS score of 1 had a severe TBI at their admission, and 9 (60.0%) were admitted >6 hours after their accident. Of the 15 deaths recorded, 3 (20.0%) were registered on day 0, 5 (33.3%) between days 1 and 6, and 7 (46.7%) between days 7 and 28.

The mean survival in our study population was 25.0 postoperative days (95% confidence interval, 23.4–26.5). Figure 2 shows the survival function of our patient population.

DISCUSSION

In sub-Saharan Africa, TBIs constitute >40.0% of all neurosurgical admissions in both the adult and the pediatric population.^{21–25} Emergency craniotomies are essential to the management of neurosurgical TBIs. They improve survival, are cost effective in low-resource settings, and should be an essential part of a health care system that is expected to deliver trauma care.^{26,27} This study is the first detailed analysis of neurosurgical trauma care provision and surgical outcomes in Central Cameroon. It describes the prehospital conditions, the craniotomy practices, and the outcomes of Cameroonian patients with TBI operated on within 72 hours of injury.

RTAs

RTAs were responsible for most TBI in our study, reflecting recent epidemiologic studies that showed that 75.0% of the 69 million people incurring TBI worldwide each year are in LMICs.²⁸ In Cameroon, the low enforcement of existing national speed limits and motorcycle helmet laws and a deficient prehospital care system have led to a steady increase in the number of RTAs and their morbimortality.^{3,8,10,29,30} Of RTA-related TBIs in our study, 80.0% involved pedestrians, motorcycle riders, or passengers. The proportion of RTA-related injury can be used as a proxy for traffic law enforcement and respect by road users.²⁹ High RTA injury should warrant preventive strategies from law enforcement agencies, ministry of health, and ministry of transportation as recommended by the United Nations. Cameroon, like all United Nations member states, committed to attaining the Sustainable Development Goals. Two targets of the Sustainable Development Goals specifically address RTA. These are target 3.6, which seeks to reduce road traffic deaths and injuries by 50% by 2020, and target 11.2, which aims to provide access to safe, affordable, accessible, and sustainable transport by 2030.

Underresourced Surgical System

Most patients present a high risk despite having a GCS score between 14 and 15. The relatively high death rate and loss to follow-up are a result of the inadequate trauma and surgical

Table 1. Patient Demographics, Clinical, and Radiologic Findings at Admission

Characteristic	n (%)
Gender	
Female	9 (9.0)
Male	91 (91.0)
Mechanism of injury	
Road traffic accident	68 (68.0)
On foot	27 (27.0)
On a motorcycle	27 (27.0)
In a car	14 (14.0)
Assault	23 (23.0)
Fall	9 (9.0)
Time to admission	
<3 hours	36 (36.0)
3–6 hours	5 (5.0)
6–12 hours	38 (38.0)
>12 hours	21 (21.0)
Referral	54 (54.0)
Prehospital transportation	
Ambulance	11 (11.0)
Nonambulance	89 (89.0)
Alcohol consumption	13 (13.0)
Clinical findings	
Glasgow Coma Scale score	
Mild (14–15)	51 (51.0)
Moderate (9–12)	23 (23.0)
Severe (3–8)	26 (26.0)
Pupils	
Normal	74 (74.0)
Anisocoria	12 (12.0)
Bilateral miosis	7 (7.0)
Bilateral mydriasis	7 (7.0)
Loss of consciousness	67 (67.0)
Lucid interval	11 (11.0)
Posttraumatic amnesia	20 (20.0)
Convulsions	9 (9.0)
Motor deficit	7 (7.0)
Sensory deficit	4 (4.0)
Aphasia	4 (4.0)
Cranial nerve III palsy	23 (23.0)
Epistaxis	14 (14.0)
Continues	

Table 1. Continued

Characteristic	n (%)
Otorrhagia	12 (12.0)
Bilateral periorbital hematoma	13 (13.0)
Papilledema	11 (11.0)
Polytrauma	23 (23.0)
Radiologic findings	
Extradural hematoma	44 (44.0)
Unilateral	38 (38.0)
Bilateral	6 (6.0)
<25 cm ³	1 (1.0)
25–30 cm ³	4 (4.0)
>30 cm ³	39 (39.0)
Subdural hematoma	24 (24.0)
Unilateral	22 (22.0)
Bilateral	2 (2.0)
Cerebral contusion	20 (20.0)
Herniation	14 (14.0)
Subfalcine	11 (11.0)
Temporal	3 (3.0)
Depressed skull fracture	46 (46.0)
Risk assessment (Masters classification)	
Mild risk	2 (2.0)
Moderate risk	24 (24.0)
High risk	74 (74.0)

system. Patients are not receiving the care that they need in time because of a delay in seeking, reaching, or receiving care. Cameroon's national prehospital service, the Emergency Medical Aid Service or *Service d'Aide Médicale d'Urgence*, and the national corps of firefighters are underresourced and underused. Patients with TBI are often transported to the closest health facilities by well-meaning individuals who have no emergency medical service training. Few health facilities have the infrastructure or workforce to manage TBI, and there is no formal communication channel between health facilities. As a result, patients visit multiple facilities before they arrive at a neurosurgical center that can provide definitive care.

Although the burden of TBIs is higher in LMICs, fewer patients reach the appropriate hospital in time. Only 11.0% of patients were driven to the hospital in an ambulance, and just 36.0% of patients were admitted within 3 hours of the accident. Time to hospital and the quality of pre-emergency care are critical to the outcome of patients with TBI and might explain the higher morbidity and mortality in our study.³¹ Gupta et al. found that 22.0% of TBI admissions in LMICs occurred more than an hour after the initial traumatism, and this adversely affected 30-day mortality.³² The golden hour of severe TBI is 2 hours in high-

Table 2. Measures of Association for Select Independent Variables and the Glasgow Outcome Scale at Postoperative Day 28 of Patients Operated on Within 72 Hours of Admission

Variable	β	Standard Error	95% Confidence Interval	P Value
Constant	4.219	0.584	3.059–5.379	<0.001*
Age	−0.024	0.007	−0.037 to −0.011	0.001†
Sex	0.390	0.382	−0.369 to 1.149	0.310
Means of prehospital transportation	0.272	0.342	−0.408 to 0.951	0.429
Time to admission	−0.105	0.092	−0.287 to 0.078	0.257
Glasgow Coma Scale	−0.642	0.138	−0.917 to −0.368	<0.001*
Pupils	0.352	0.127	0.100–0.604	0.007†
Extradural hematoma	0.017	0.248	−0.475 to 0.510	0.944
Subdural hematoma	−0.623	0.295	−1.210 to −0.036	0.038†
Cerebral contusion	−0.417	0.271	−0.955 to 0.122	0.128
Polytrauma	0.176	0.266	−0.352 to 0.704	0.510

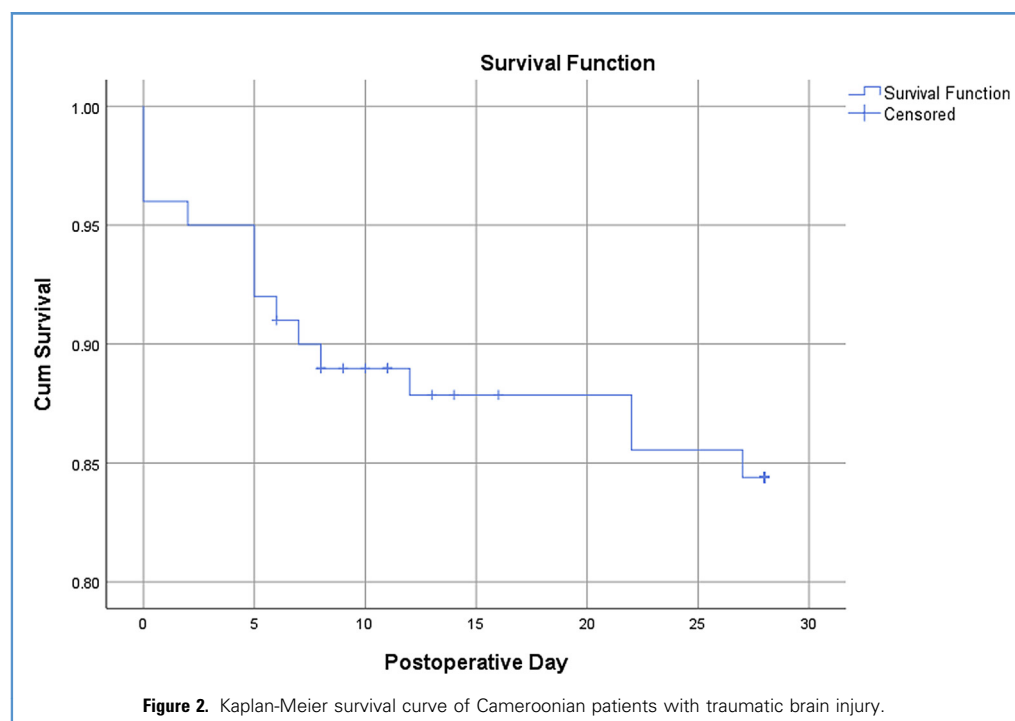
* <0.001

† <0.05

income countries (HICs) and 4 hours in LMICs. TBI in LMICs is a condition of young adult males, whereas, in HICs, it affects older individuals.³³ Young adults have a better tolerance to TBIs and can receive delayed care with similar outcomes.³⁴ Below the golden-hour limits, there are no additional benefits, and above this limit, the mortality increases with each additional minute.^{12,35–37}

There is a marked difference between the time to admission in HICs and those of LMICs. HICs admit most patients with TBI within 60 minutes of the injury^{36,37} whereas most LMICs admit the

bulk of patients with TBI beyond the 6-hour mark.^{2,8,28,30,38} These disparities have implications on the applicability of international neurotrauma guidelines and the outcome of patients in low-resource settings. For example, the recently reported Corticosteroid randomisation after significant head injury-3 (CRASH-3) trial showed the efficacy of tranexamic acid in the management of patients with TBI with GCS score ≤ 12 within 3 hours of injury. The population defined by CRASH-3 constitutes <20.0% of patients with TBI in Cameroon and other LMICs.^{8,28,30,38} Hence, although

**Figure 2.** Kaplan-Meier survival curve of Cameroonian patients with traumatic brain injury.

this is a major neurotrauma research breakthrough, it will be challenging to see its effects in the populations most affected by TBIs. There is, therefore, a need to develop context-specific and evidence-based clinical recommendations for low-resource settings.^{39,40}

There are no devices for the measurement of intracranial pressure at this Cameroonian neurosurgical center, so neurosurgeons rely on a combination of clinical and radiologic findings to decide whether or not to operate. In addition, because patients pay for their health expenses out of pocket, their management is often delayed until they can pay a minimum deposit. We recommend a study to identify the excess morbidity and mortality in patients with TBI caused by the delay in obtaining appropriate neurosurgical care in Cameroon.

Policy Recommendations

Evidence-based system-level policies are needed to improve access to emergency neurosurgical care in LMICs.⁴¹ Corley et al.⁴² proposed a minimum workforce density of 1 neurosurgeon per 212,000 population to manage patients with TBIs adequately. For Cameroon to meet this target, it must train at least 93 additional neurosurgeons by 2030, assuming no retirements and a population growth rate of 0. An increase in the neurosurgical training capacity can help to mitigate this gap. The increase in training capacity can be achieved in-country through the human resources for health improvement components of National Surgical, Obstetric, and Anesthesia Plans. Alternatively, training can be organized regionally, as is currently practiced through accredited WFNS training centers.⁴³ By increasing the number and geographic distribution of neurosurgical centers, governments can increase geographic proximity and improve patient outcomes. The target for geographic proximity has been set at 80.0% of the population living <4 hours away from a WFNS level 1 facility (neurotrauma capable).⁴¹ Other proposed strategies to decrease the morbidity and mortality of patients with TBI include the incorporation of neurotrauma care into universal health coverage plans and the use of the World Health Organization's International Registry for Trauma and Emergency Care.⁴² The objective is to diminish out-of-pocket expenditures, which are partly responsible for the delay in receiving timely and appropriate neurotrauma care, and to monitor TBI data.

Limitations

The findings in our series are limited by the fact that a single Cameroonian center provided data. Moreover, we had limited data on the follow-up and the longitudinal outcomes of our patients.

We lacked data for the 12 patients whom we lost to follow-up, and the exclusion of >50 patients who were operated on >72 hours from injury is another limitation of this study. Patients who were operated on >72 hours after their admission are expected to have worse outcomes, and this could increase postoperative mortality. The recording of the delay from injury to admission in 3-hour time intervals is another limitation of our study. As a result of this situation, we were unable to compare our findings with the golden-hour recommendations.

CONCLUSIONS

Young adult males are the most affected by TBIs, and their lesions are primarily caused by RTAs. In this Cameroonian study limited to patients admitted within 72 hours after TBI, 6 of 10 patients were admitted >6 hours after the initial traumatic event, and 90.0% of patients were transported to the hospital in non-ambulance vehicles. Contextualized improvements in prehospital care must be developed to improve infrastructure. These improvements include strategies aimed at increasing the workforce and improving the health infrastructure and the health information management systems in Cameroon. Further research should be carried out to assess the excess morbidity and mortality caused by delays in receiving care.

CRedit AUTHORSHIP CONTRIBUTION STATEMENT

Régis Takoukam: Conceptualization, Methodology, Investigation, Resources, Writing - original draft. **Ulrick Sidney Kanmounye:** Validation, Formal analysis, Resources, Writing - original draft, Writing - review & editing, Visualization. **Faith C. Robertson:** Validation, Formal analysis, Writing - review & editing. **Kathrin Zimmerman:** Validation, Writing - review & editing. **Stéphane Nguemba:** Writing - review & editing. **Jean W. Lartigue:** Writing - review & editing. **Kee B. Park:** Supervision, Methodology, Validation, Writing - review & editing. **Bello Figuim:** Supervision, Methodology, Validation, Writing - review & editing. **Ignatius Esene:** Supervision, Methodology, Validation, Writing - review & editing.

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