Traumatic Brain Injury and Infectious Encephalopathy in Children From Four Resource-Limited Settings in Africa

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DOI: 10.1097/PCC.0000000000001554

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website (http://journals.lww.com/pccmjournal).

Drs. Fink's, Bacha's, and Kochanek's institutions received funding from the Laerdal Foundation. Dr. Kumar received support for article research from a Laerdal grant. Dr. Wilson's institution received funding from the University of Pittsburgh. Dr. Kochanek disclosed that he holds several patents/provisional patents in the field of acute brain injury, and his research is funded by the National Institutes of Health and the U.S. Department of Defense (although this study was not supported by those grants nor are the patents relevant to the current study); he received funding from the Society of Critical Care Medicine and the World Federation of Pediatric Intensive and Critical Care Societies as Editor-in-Chief of Pediatric Critical Care Medicine; and he has served as an expert witness on a number of cases in the field of neurocritical care and resuscitation. The remaining authors have disclosed that they do not have any potential conflicts of interest.

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Objectives: To assess the frequency, interventions, and outcomes of children presenting with traumatic brain injury or infectious encephalopathy in low-resource settings.

Design: Prospective study.

Setting: Four hospitals in Sub-Saharan Africa.

Patients: Children age 1 day to 17 years old evaluated at the hospital with traumatic brain injury or infectious encephalopathy.

Interventions: None.

Measurements and Main Results: We evaluated the frequency and outcomes of children presenting consecutively over 4 weeks to any hospital department with traumatic brain injury or infectious encephalopathy. Pediatric Cerebral Performance Category score was assessed pre morbidity and at hospital discharge. Overall, 130 children were studied (58 [45%] had traumatic brain injury) from hospitals in Ethiopia ($n = 51$), Kenya ($n = 50$), Rwanda ($n = 20$), and Ghana ($n = 7$). Forty-six percent had no prehospital care, and 64% required interhospital transport over 18 km (1–521 km). On comparing traumatic brain injury with infectious encephalopathy, there was no difference in presentation with altered mental state (80% vs 82%), but a greater proportion of traumatic brain injury cases had loss of consciousness (80% vs 53%; $p = 0.004$). Traumatic brain injury patients were older (median [range], 120 mo [6–204 mo] vs 13 mo [0.3–204 mo]), p value of less than 0.001, and more likely male (73% vs 51%), p value of less than 0.01. In 78% of infectious encephalopathy cases, cause was unknown. More infectious encephalopathy cases had a seizure (69% vs 12%; $p < 0.001$). In regard to outcome, infectious encephalopathy versus traumatic brain injury: hospital lengths of stay were longer for infectious encephalopathy (8 d [2–30 d] vs 4 d [1–36 d]; $p = 0.003$), discharge rate to home, or for inpatient rehabilitation, or death differed between infectious encephalopathy (85%, 1%, and 13%) and traumatic brain injury (79%, 12%, and 1%), respectively, p value equals to 0.044. There was no difference in the proportion of children surviving with normal or mild disability (73% traumatic brain injury vs 79% infectious encephalopathy; $p = 0.526$).

Conclusions: The epidemiology and outcomes of pediatric traumatic brain injury and infectious encephalopathy varied by center and disease. To improve outcomes of these conditions in low-resource setting, focus should be on neurocritical care protocols for pre-hospital, hospital, and rehabilitative care. (*Pediatr Crit Care Med* 2018; XX:00–00)

Key Words: central nervous system infection; child; epidemiology; traumatic brain injury; low-resource setting

Worldwide, traumatic brain injury (TBI) and infectious encephalopathy (IE) are leading causes of seizures and altered consciousness (1). In survivors, there is significant risk of disability. In low-resource settings (LRSs), advances in treatment and prevention have improved survival from infection, but deaths due to injuries, most commonly TBI, are increasing (2–6). Decreasing child deaths and road traffic accidents are prioritized by the United Nations Sustainability Development Goals (7). While multicenter data exist regarding the frequency and outcomes of IE in LRS, little is known about children with TBI (8–10).

The World Health Organization pediatric "Emergency Triage, Assessment and Treatment" (ETAT) guidelines focus on providing updated guidance in clinical care for seriously ill infants and children presenting with critical danger signs (11). The aims are to provide oxygen therapy and fluid management when needed, as well as management for seizures and altered consciousness. Centers in LRS are in need of and may be able to support more advanced neurocritical care protocols to improve outcomes for pediatric patients.

Therefore, in this study, we have surveyed the epidemiology, treatment, and interventions used, outcomes, and barriers to emergency and supportive care for children with TBI and IE in four LRS. Our long-term objective is to use these data to develop a curriculum, clinical guidelines, and quality and research programs for medical practitioners as well as advocate resource allocations found to be needed to improve child outcomes in LRS.

MATERIALS AND METHODS

The Institutional Review Board at the University of Pittsburgh approved the Coordinating Center (Pittsburgh, PA) and its investigators for this observational study. In addition, individual investigators at each enrolling obtained local regulatory approval. This was carried out at four centers in Africa: Addis Ababa University, Ethiopia; Kenyatta National Hospital, Kenya; University Teaching Hospital of Kigali, Rwanda; and the Wenchi Methodist Hospital, Ghana.

We recruited consecutive children 1 day to 17 years old who presented to each hospital's emergency department, ward, or ICU with suspected or confirmed TBI (Ethiopia, Kenya, and Rwanda) or IE (Ethiopia, Kenya, Rwanda, and Ghana). Site investigators, who all provided clinical care or consultation at their respective centers, identified children for prospective study over a 4-week period. Investigator and patient participation was voluntary, and no remuneration was given, but research assistants were contracted as per site guidelines.

The Case Report Form included information on hospital and patient demographics, disease, monitoring, therapies, comorbidities, severity of injury, and outcomes. Altered Mental Status scale was categorized into agitation, somnolence, and slow verbal response. Loss of consciousness was reported as had occurred in addition to duration if known. The Glasgow Coma Scale (GCS) score on presentation to the hospital emergency department was used for analysis (12). For the purposes of this study, increasing levels of care occurred from the emergency department to the ward and to the operating room or ICU.

Deidentified data were securely transferred to the coordinating center for quality assurance and analysis. Data were screened for missing or implausible information, and queries were issued to the site.

The primary outcome was the frequency of TBI and IE, hospital survival, and morbidity. Morbidity was determined at hospital discharge using Pediatric Cerebral Performance Category (PCPC) score (13). PCPC scores were calculated by the center investigators using the medical chart. Favorable outcome was defined as a PCPC score of 1 or 2 at hospital discharge. Secondary outcomes included prehospital care. Lengths of stay analyses were performed for children admitted to the ward, operating room, or ICU.

Descriptive statistics are presented as median (interquartile range [IQR]). Data were analyzed using Kruskal-Wallis, Mann-Whitney, Fisher exact, and chi-square tests as appropriate. Statistical analysis by center was not performed because of the limited number of centers and children. The majority of variables had less than 10% missing data, and missing data were not imputed (thus sample sizes for variables and denominators varied). Comparisons between TBI and IE were performed including all children from all centers. All p values were two sided,

TABLE 1. Center Characteristics

Variables	Ethiopia, *n* = 53 (41%)	Kenya, *n* = 50 (38%)	Rwanda, *n* = 20 (15%)	Ghana, *n* = 7 (5%)
City	Addis Ababa	Nairobi	Kigali	Wenchi
Population	3.4 million	3.2 million	600,000	40,000
Emergency medical system available/cost	Yes	Yes/500 USD/yr	Yes/1 USD	Yes
University affiliated	Yes	Yes	Yes	No
Public	Yes	Yes	Yes	Yes
Number of pediatric beds	176	450	57	35
Number of pediatric emergency department admissions	3,000	600–800	2,400	NA
Number of pediatric hospital admissions	7,885	4,250	1,230	3,578
Number of PICU beds	4	10	5	0
Number of PICU admissions	270	300	108	NA
ICU nurse ratio	1:1 (for mechanically ventilated patients)	1:2	1:1	1:2
Hospital resources				
O_2	Yes	Yes	Yes	Yes
IV fluids	Yes	Yes	Yes	Yes
Intubation	Yes	Yes	Yes	No
Cardiac monitoring	Yes	Yes	Yes	Yes
x-ray	Yes	Yes	Yes	Yes
CT scan	Yes	Yes	Yes	No
Trauma team	No	No	No	No
Neurosurgeon	Yes	Yes	Yes	No

NA = not available, USD = U.S. dollar.

and a *p* value of less than 0.05 was considered statistically significant. The Statistical Package for the Social Sciences Version 20 (Armonk, NY) was used for statistical analyses. This article was written according to the STrengthening the Reporting of OBservational studies in Epidemiology statement (14).

RESULTS

Study Center and Patient Characteristics

All hospitals, except the one in Ghana, are affiliated with a university, and all are public hospitals (**Table 1**). All centers were able to provide oxygen, IV fluids, and noninvasive cardiovascular monitoring, but healthcare providers at the Ghana center did not use endotracheal intubation, have a neurosurgeon available, or have brain CT scanners. No center had explicit clinical protocols for TBI or IE, and none had an organized trauma team. All centers had a general surgeon available to provide clinical care.

Overall, 130 children were enrolled, with 58 (44.6%) presenting with TBI and 72 (55.4%) presenting with IE (**Table 2**). In the three centers recruiting both TBI and IE patients, TBI children were older than IE children (median [range], 120 mo [6–204 mo] vs 13 mo [0.3–204 mo]; $p < 0.001$), and there was a greater proportion of male children (73% vs 51%), *p* value of less than 0.01.

Most children were enrolled from either the center in Ethiopia (41%) or the center in Kenya (39%). The Ethiopian (TBI, 72%) and Rwandan (TBI, 60%) centers enrolled more children with TBI when compared with the Kenyan center (TBI, 16%) (**Supplemental Table 1**, Supplemental Digital Content 1, http://links.lww.com/PCC/A650). The Ghana site enrolled only IE cases ($n = 7$) because of limitation in regulatory approval.

Leading categories of insurance status were self-insured (73%) at the Ethiopian center, governmental/public insurance in Kenya (57%) and Rwanda (90%), and no documented insurance for 57% of children in Ghana.

Prehospital Care

The mode of transport used to get to hospital differed between cases of TBI and IE (**Table 3**). Thirty-four children (59%) with TBI were transported via ground ambulance, and 29 children (41%) with IE were transported via public means such as taxi cab. In cases where ground ambulance was not used, emergency medical support on transport to the hospital was either unavailable or unaffordable. Overall, 59 children (46%) had no prehospital care. The remainder of

TABLE 2. Patient Characteristics by Disease

Patient Characteristics	Overall, *n* = 130, *n* (%) or Median (Minimum – Maximum)	Traumatic Brain Injury, *n* = 58, *n* (%) or Median (Minimum – Maximum)	Infectious Encephalopathy, *n* = 72, *n* (%) or Median (Minimum – Maximum)	*p*
Age (mo)	*n* = 129, 36 (0.33–204)	*n* = 57, 120 (6–204)	*n* = 72, 12.7 (0.33–204)	< 0.001
Male	*n* = 127, 77 (61)	*n* = 56, 41 (73)	*n* = 71, 36 (51)	0.011
Health insurance	*n* = 127	*n* = 56	*n* = 71	0.201
Self	56 (44)	29 (52)	27 (38)	
Government	33 (26)	9 (16)	24 (34)	
Public	27 (21)	13 (23)	14 (20)	
Private	2 (2)	1 (2)	1 (1)	
None	9 (7)	4 (7)	5 (7)	

Number of data points available for each variable provided, followed by descriptive data.

TABLE 3. Transport and Prehospital Care by Disease

Transport/Prehospital Care Variable	Overall, *n* = 130, *n* (%) or Median (Minimum – Maximum)	Traumatic Brain Injury, *n* = 58, *n* (%) or Median (Minimum – Maximum)	Infectious Encephalopathy, *n* = 72, *n* (%) or Median (Minimum – Maximum)	*p*
Transport to hospital	*n* = 129	*n* = 58	*n* = 71	0.002
Ground ambulance	56 (43)	34 (59)	22 (31)	
Public (taxi)	37 (29)	8 (14)	29 (41)	
Public (bus)	12 (9)	3 (5)	9 (13)	
Private motorized	8 (6)	5 (9)	3 (4)	
Private nonmotorized	7 (5)	2 (3)	5 (7)	
Walk-in	5 (4)	3 (5)	2 (3)	
Other	3 (2)	2 (3)	1 (1)	
Police	1 (1)	1 (2)	0 (0)	
Interhospital transfer	*n* = 121, 77 (64)	*n* = 56, 45 (78)	*n* = 65, 32 (44)	< 0.001
Transport time to hospital (min)	*n* = 70, 60 (1–540)	*n* = 45, 90 (10–540)	*n* = 25, 60 (1–120)	0.007
Distance to hospital (km)	*n* = 95, 18 (1–521)	*n* = 51, 60 (1–521)	*n* = 44, 15.5 (1–375)	0.007
Level of prehospital care	*n* = 127	*n* = 57	*n* = 70	0.325
None	59 (46)	24 (42)	35 (50)	
Basic life support	65 (51)	32 (56)	33 (47)	
Advanced life support	2 (2)	0 (0)	2 (3)	
Unknown	1 (1)	1 (2)	0 (0)	
No emergency medical service	*n* = 65	*n* = 29	*n* = 36	0.006
Not available	47 (72)	26 (90)	21 (58)	
Unaffordable	15 (23)	2 (7)	13 (36)	
Other	3 (5)	1 (3)	2 (6)	

children were transported by personnel with either basic life support (BLS) (51%) or advanced life support (ALS) (3%) training. There was no difference in favorable outcome by level of prehospital care ($p = 0.644$) or prehospital transport by emergency medical services versus other categories ($p = 0.127$). The number of children transported by emergency medical services versus other means had emergency department recorded GCS score of 15 (48% vs 53%), GCS score of

9–14 (26% vs 39%), and GCS score of 3–8 (26% vs 8%), *p* value equals to 0.111.

Seventy-seven children (64%) in the series had required interhospital transport to the center, which took place over a distance of 18 km (1–521 km), with duration 60 minutes (1–540 min). Children with TBI underwent interhospital transport more frequently than children with IE (45/58 vs 32/72, $p < 0.001$), over longer distances (60 km [1–521 km] vs 16 km [1–375 km]; $p = 0.007$) and time (90 min [10–540 min] vs 60 min [1–120 min]; $p = 0.007$). Longer duration of transport to the hospital was associated with home versus hospital disposition (median [IQR], 120 min [120–240 min] vs 60 min [30–90 min]; $p = 0.0006$) but not favorable outcome ($p = 0.489$).

Ghana was the only center without any children transported via ground ambulance due to lack of access; instead, children were transported via public transportation (71%) or as walk-ins (29%) (**Supplemental Table 2**, Supplemental Digital Content 1, http://links.lww.com/PCC/A650). In the other three centers, more than half of enrolled children had prior interhospital transport. BLS-trained personnel transported 57% of cases in Ethiopia, 59% in Kenya, 35% in Rwanda.

Disease Characteristics

The leading cause of TBI was blunt trauma (93%) from either high-energy fall (36%) or traffic accident (22%). Fifty-three percent of TBI cases had multiple trauma (**Table 4**). In 49 cases (85%), the injuries were reported to be accidental; five (9%) were due to assault, and one (2%) was self-inflicted. There was no specific cause identified in 58 cases (78%) with IE. Among the children with an etiology identified, the most common causes were cerebral malaria seven (10%) and *Mycobacterium tuberculosis* three (4%).

On comparing TBI and IE, there was no difference in the proportion presenting any category of altered mental status (80% vs 82%; $p = 0.814$). More children with TBI had lost consciousness (80% vs 53%; $p = 0.004$), with 66% of those with TBI and 68% of those with IE having lost consciousness for greater than 5 minutes. A greater proportion of children with IE had had a clinical seizure (69% vs 12%; $p < 0.001$). GCS score in the emergency department was reported for 97% of children with TBI and 31% with IE. There were no differences in presenting GCS severity categories (15, 9–14, 3–8) by condition, *p* value equals to 0.396. In children with any loss of consciousness, emergency department GCS score was 15 in 17 (40%), 9–14 in 14 (33%), and 3–8 in 11 (26%).

Patient Outcomes

Management in the emergency department was the highest level of care for 40 children (71%) with TBI and 12 children (20%) with IE (**Table 5**). All but three of 33 (9%) with GCS score less than 15 were admitted to the hospital. The Rwanda center had the most children with highest level of care being the emergency department (85%) followed by Ethiopia (69%) (**Supplemental Table 3**, Supplemental Digital Content 1, http://links.lww.com/PCC/A650). All children presenting to the Kenyan and Ghana centers were admitted to the hospital.

Nine children (16%) with TBI were taken to the operating room (vs no children with IE). Forty-four children (72%) with IE were admitted to the ward versus three (5%) children with TBI. Four children each with TBI (7%) and IE (7%) were admitted to the ICU: mechanical ventilation was used for 11 days (7–16 d) and 0.5 days (0–4 d), *p* value equals to 0.032 in TBI and IE cases, respectively. ICU length of stay was 5 days (1–20 d) overall and was similar between TBI and IE patients. Hospital length of stay was 7 days (2–36 d) overall and was similar between TBI and IE patients.

Hospital dispositions included discharge home, transfer for inpatient rehabilitation, or death: these respective rates differed between TBI (79%, 12%, and 9%) and IE (85%, 1%, and 13%), *p* value equals to 0.044. There was no difference in the proportion of children surviving with normal or mild disability (favorable outcome) (73% TBI vs 79% IE; $p = 0.526$). Of children with favorable outcomes, 31 (62%) had emergency department GCS score of 15, 16 (32%) had GCS score of 9–14, and three (6%) had GCS score of 3–8, *p* value of less than 0.001. Favorable outcome by highest level of care occurred in 40 children (83%) in the emergency department, 37 (82%) in the ward, six (67%) in the operating room, and two (25%) in the ICU, *p* value equals to 0.002. Of the 41 children (34%) who had a worse PCPC score at hospital discharge, more occurred in children with TBI than IE (46% vs 24%; $p = 0.012$). More children with IE received physical (80% vs 35%; $p < 0.001$) and occupational (59% vs 16%; $p < 0.001$) therapy, but more children with TBI were discharged to inpatient rehabilitation (12% vs 1.4%) a resource not available at every center.

Twenty-one percent of children from the Rwandan center were discharged to inpatient rehabilitation. Eight percent of children at the Ethiopian center were discharged home with outpatient rehabilitation. The other centers do not have inpatient rehabilitation available to their pediatric patients. Mortality ranged from 5% to 29% across centers, with the highest in Ghana. Children with no or mild disability at discharge ranged from 57% to 83% among the four centers.

DISCUSSION

The ETAT guidelines and updates from 2005 and 2016 have improved care and outcomes for children in LRS (11, 15, 16). However, management of children with altered mental state due to infection or trauma remain basic and focused on initial care at the healthcare facility when comprehensive care is needed (17). Large prospective epidemiologic studies that could serve to inform clinical, legislative, and research gaps to improve outcomes are lacking (6). The main objectives of the Prevalence of Acute critical Neurologic disease in children: a Global Epidemiological Assessment (18) program are to investigate the access to care, epidemiology, treatments, and outcomes for neurocritical conditions in children to identify key inadequate systematic and local care processes amenable to interventions that improve outcomes. The main findings of this study in children with IE and TBI, in four centers in Africa, are as follows: 1) TBI and IE occurred with similar frequency in children but differed among centers; 2) lack of access to quality prehospital care personnel

TABLE 4. Illness Characteristics by Disease

Illness Variable	TBI, *n* = 58	IE, *n* = 72	*p*
Etiology IE, *n* (%)		*n* = 72	
Encephalopathy, unspecified		56 (78)	
Cerebral malaria		7 (10)	
Mycobacterium tuberculosis		3 (4)	
Encephalitis, unspecified		3 (4)	
Bacterial meningitis, unspecified		2 (3)	
Abscess, unspecified		1 (1)	
Etiology TBI, *n* (%)	*n* = 58		
Blunt	54 (93)		
Penetrating	2 (3)		
Unknown	2 (3)		
Mechanism, *n* (%)	*n* = 58		
High-energy fall	21 (36)		
Motorized vehicle	13 (22)		
Blunt object	10 (17)		
Pedestrian	4 (7)		
Low-energy fall	4 (7)		
Sharp object	2 (3)		
Motorcycle	2 (3)		
Other/unknown	2 (3)		
Intent, *n* (%)	*n* = 57		
Accident	49 (86)		
Assault	5 (9)		
Self-inflicted	1 (2)		
Other/unknown	2 (4)		
Palpable skull fracture, *n* (%)	*n* = 47, 19 (40)		
Multiple trauma, *n* (%)	*n* = 51, 27 (53)		
Glasgow Coma Scale score—emergency department, *n* (%)	*n* = 56	*n* = 22	0.396
15	28 (50)	11 (50)	
9–14	16 (29)	9 (41)	
3–8	12 (21)	2 (9)	
Altered mental status, *n* (%)	*n* = 54, 43 (80)	*n* = 62, 51 (82)	0.814
Altered Mental Status scale, *n* (%)	*n* = 40	*n* = 47	0.018
Agitation	13 (33)	18 (38)	
Somnolence	12 (30)	23 (49)	
Slow verbal response	10 (25)	6 (13)	
Other	5 (13)	0 (0)	
Loss of consciousness, *n* (%)	*n* = 55, 44 (80)	*n* = 55, 29 (54)	0.004
Loss of consciousness duration, *n* (%)	*n* = 41	*n* = 25	0.866
0–60 s	7 (17)	5 (20)	
1–5 min	7 (17)	3 (12)	
> 5 min	27 (66)	17 (68)	
Seizure, *n* (%)	*n* = 50, 6 (12)	*n* = 61, 42 (69)	< 0.001

IE = infectious encephalopathy, TBI = traumatic brain injury.

and transport systems; 3) absence of organized trauma and neurocritical care triage, diagnostics, and clinical care; and 4) limited routine assessment and treatment of disability through rehabilitation. We believe that each of these issues should be addressed in systematic fashion to improve outcomes.

The true burden of TBI and IE in children in LRS is unknown, but morbidity and mortality due to these conditions carry enormous impact (19). Trauma, especially TBI, is an increasingly important cause of death in children worldwide, with more than double the frequency in low-middle income versus high-income countries leading to 830,000 child deaths in 2004 (1, 20, 21). A qualitative review of publications of pediatric TBI worldwide (*n* = 165,000 children) found that mild TBI (GCS, 14–15) accounted for 80% of TBI cases, and overall mortality ranged from 1% to 7% (22). Focusing on LRS, a 12-year retrospective analysis of pediatric trauma deaths (78/905 total deaths) in a Nigerian trauma center found that TBI was the most common injury (54%), although unlike in our study, road traffic crashes were the leading etiology of trauma deaths (23). In South Africa, of 137 children with severe TBI, the mortality rate was 14%, with most due to road traffic accidents but also due to falls and interpersonal violence, similar to our findings (24). Cases of cerebral malaria were approximated at 2 million per year, mostly in children in Sub-Saharan Africa with hospital mortality rates estimated at 20% (25). Survivors are at increased risk of epilepsy, cognitive, motor, and emotional disabilities (8). Although the true incidence and outcomes of TBI and IE are challenging to grasp (e.g., due to lack of access to care, uncertainties in verbal

TABLE 5. Outcomes by Disease

Outcome Variable	Overall, *n* = 130, *n* (%) or Median (Minimum – Maximum)	Traumatic Brain Injury, *n* = 58, *n* (%) or Median (Minimum – Maximum)	Infectious Encephalopathy, *n* = 72, *n* (%) or Median (Minimum – Maximum)	*p*
Highest level of in-hospital care	*n* = 117	*n* = 56	*n* = 61	< 0.001
Emergency department	52 (44)	40 (71)	12 (20)	
Ward	47 (40)	3 (5)	44 (72)	
Operating room	9 (8)	9 (16)	0 (0)	
ICU	8 (7)	4 (7)	4 (7)	
Unknown	1 (1)	0 (0)	1 (2)	
Mechanical ventilation (d)	*n* = 7, 4 (0–16)	*n* = 3, 11 (7–16)	*n* = 4, 0.5 (0–4)	0.032
Hospital LOS (d)	*n* = 57, 7 (2–36)	*n* = 13, 7 (3–36)	*n* = 44, 7 (2–30)	0.522
ICU LOS (d)	*n* = 7, 5 (1–20)	*n* = 3, 11 (4–20)	*n* = 4, 4.5 (1–5)	0.208
Disposition at discharge	*n* = 128	*n* = 57	*n* = 71	0.044
Home	105 (82)	45 (79)	60 (85)	
Inpatient rehabilitation	8 (6)	7 (12)	1 (1)	
Skilled nursing facility	1 (1)	0 (0)	1 (1)	
Died	14 (11)	5 (9)	9 (13)	
Pre-PCPC score 1–2 (normal or mild disability)	*n* = 121, 116 (96)	*n* = 56, 54 (96)	*n* = 65, 62 (95)	1.000
Post-PCPC score 1–2 (normal or mild disability)	*n* = 122, 93 (76)	*n* = 56, 41 (73)	*n* = 66, 52 (79)	0.526
Mortality	*n* = 128, 14 (11)	*n* = 57, 5 (9)	*n* = 71, 9 (13)	0.576

LOS = length of stay, PCPC = Pediatric Cerebral Performance Category.

autopsy accuracy in children dying outside the hospital, lack of diagnostics and registries), these conditions indisputably require urgent attention and resources.

Most children with TBI and IE had depressed mental status and significant loss of consciousness at the time of presentation, but many of them lacked access to emergency transport systems and arrived at hospital via public transport or walk-in. In addition, many children required interhospital transfer, presumably for higher level care. Many and nearly all children lacked access to prehospital personnel trained in either BLS or ALS, respectively, critical for children at risk of needing airway and circulatory interventions (26–28). This lack of availability and access to ALS-trained prehospital emergency medical personnel impaired our ability to demonstrate any impact of ALS on outcome. Similarly, children in the Nigerian study arrived to the hospital on average 18 hours post trauma (range, 1 hr to 4 d), due to lack of prehospital services and nearly half having had initial outpatient or traditional treatments prior to arriving at the hospital (23). Despite the lack of association between prehospital transportation method and outcome, we argue that access to high-quality prehospital emergency transport systems are a critically needed resource that should be prioritized for development (29).

Our study showed that there were local, active triage systems for TBI within the emergency departments, since over 70% of children could be discharged home after evaluation. However, none of the centers had explicit clinical protocols, and none had an organized trauma team—all used a general surgeon to supervise clinical trauma care. Notably, few children with TBI needed care in the operating room and ICU, but none received intracranial pressure monitoring. The utility of invasive and noninvasive mechanical ventilation for children with TBI or IE in resource-limited settings is scarce. Our findings agree with previous work indicating a distinct need for hospital-based TBI assessment and treatment guidelines for LRS that are adaptable by resource availability (30). Unlike in TBI, most of the children with IE were admitted to the hospital. This may be due in part to the fact that more children with IE had seizures and somnolence noted, but also because IE would typically require ongoing antimicrobial treatment whereas evidence and guidelines for who might benefit from hospital monitoring among children with varying degrees of TBI severity in LRS are unknown.

Cognitive impairment and other functional disabilities due to TBI and IE in children living in LRS represent a public health crisis (31–36). In our study, survival and disability outcomes were similar for children with TBI and IE. Notably, although nearly all children had no or mild premorbid disability, one in four children had moderate or worse neurologic disability at hospital discharge. Despite this observation, very few children were treated in inpatient rehabilitation facilities. Similar to our findings in emergency medical assistance and transportation, access to and data supporting the approach to rehabilitation for children with TBI and IE are scarce in low-to-middle income communities (37).

Taken together, our findings, although unique, represent pediatric patients with access to tertiary-care centers in LRS in Africa limiting the generalization of findings. Three of the participating centers were large, urban, tertiary-care academic hospitals. These centers had many of their patients transported to their facility after presenting to another hospital, and thus our findings may not reflect children seen at less-resourced community hospitals. Data from children who died before reaching a medical facility for care and children with milder conditions who did not present to the hospital were not collected in this study. Long-term outcomes including functional disability, quality of life, and return to activities of daily living and school were not assessed in this study. The PCPC score may be less informative in infants than in older children. Seasonal variation of disease was not accounted for in this study.

The United Nations Sustainability Development Goal 3 is to ensure healthy lives and promote well-being for all at all ages, including ending preventable deaths of newborns and children less than 5 years old by 2030 and halving global deaths and injuries from road traffic accidents by 2020.

Our study has also identified important priority considerations for future actions to address these goals. For example, the frequent lack of prehospital care, lack of diagnostic and treatment guidelines for pediatric neurocritical care, and minimal use and availability of rehabilitation services for children with TBI and IE in LRS suggest that these domains represent targets that may improve outcomes (38). Educational efforts including didactic curricula, simulation, and other innovative strategies for healthcare providers and families of children in LRS with neurocritical illness should be developed. Quality and research programs to monitor effects of local and systematic interventions on patient outcomes are needed (39).

CONCLUSIONS

The epidemiology and outcomes of pediatric TBI and IE varied by center and disease in four centers in Africa. To improve outcomes for these children in LRS, focus should be on applying resources to develop evidence that support the development of neurocritical care diagnostic and treatment protocols and educational curricula for prehospital, hospital, and rehabilitative care.

ACKNOWLEDGMENTS

We thank Eric Yablonsky for his work on data quality and organization. The investigators appreciated the nonfinancial support of the following groups committed to the provision of excellent clinical care and research: Pediatric Acute Lung Injury and Sepsis Investigators, World Federation of Pediatric Intensive and Critical Care, and Pediatric Neurocritical Care Research Group. We are grateful to the patients, families, research staff, nurses, and physicians of all centers in this study for their generous efforts to help improve the outcomes of children with traumatic brain injury and infectious encephalopathy in low-resource setting.

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