Check for updates

Prehospital Factors Associated with Discharge Outcomes: Baseline Data from the Andhra Pradesh Traumatic Brain Injury Project

Kodanda Ram[1], Kadali VaraPrasad[1], Murali K. Krishna[1], Nithya Kannan[2,3], Venkataraman Sundar[4], Mathew Joseph[5], Virendar D. Sinha[6], Dhaval Shukla[7], Gopalakrishnan Gururaj[8], Raj K. Narayan[9], Jogi V. Pattisapu[10], Monica S. Vavilala[2,3]

OBJECTIVE: **Strategies to improve traumatic brain injury (TBI) outcomes in India are ill defined. The objective of this study was to examine baseline prehospital (PH) factors associated with outcomes from the Andhra Pradesh Traumatic Brain Injury Project.**

METHODS: **We conducted a prospective observational cohort study of adult patients with TBI admitted to the primary referral hospital. Modes of injury, prehospital care and transport, and factors associated with increased in-hospital mortality were evaluated. Poisson regression with robust error variance and adjusted attributable risk percent estimates determined factors associated with outcomes.**

RESULTS: **A total of 447 adults (38% with mild TBI, 30% with moderate TBI, and 32% with severe TBI; 81% men) with isolated TBI (89%) from road traffic accidents (48.1%) or falls (46.5%) were enrolled. Of the patients, 45.7% were transported by ambulance, 61% had scalp/facial bleeding, 11% had respiratory distress, and 7% had cervical spine stabilization. Of these, 25.3% died and 34% had unfavorable outcomes. Among 335 direct admits, 45% traveled more than 50 km and nearly 20% traveled more than 100 km. Bleeding was associated with higher mortality (adjusted relative risk [aRR], 1.56; 95% confidence interval [CI], 1.05—2.31) and unfavorable outcome (aRR, 1.60; 95% CI, 1.18—2.17). Of the patients, 45 (31%) with severe TBI received PH airway management prior to definitive treatment, and respiratory distress was associated with unfavorable discharge outcomes (aRR, 1.23; 95% CI, 1.00—1.51).**

CONCLUSIONS: **Patients with TBI often received treatment far away from injury, bypassing closer hospitals. Scalp/facial bleeding was common and associated with unfavorable outcomes. Ambulance use was infrequent, and few patients received PH airway management, hemorrhage control, or cervical spine stabilization when needed.**

INTRODUCTION

Traumatic brain injury (TBI) is a major public health problem in low- to middle-income countries.[1,2] In India, approximately 1.6 million individuals sustain TBI annually,

Key words
- Outcomes
- Risk factors
- Trauma
- Trauma system
- Traumatic brain injury
- Triage

Abbreviations and Acronyms
AR%: Adjusted attributable risk percent
aRR: Adjusted relative risk
CI: Confidence interval
CT: Computed tomography
ED: Emergency department
GCS: Glasgow Coma Scale
ICU: Intensive care unit
IQR: Interquartile range
KGH: King George Hospital
LOS: Length of stay
OR: Operating room
PH: Prehospital
TBI: Traumatic brain injury

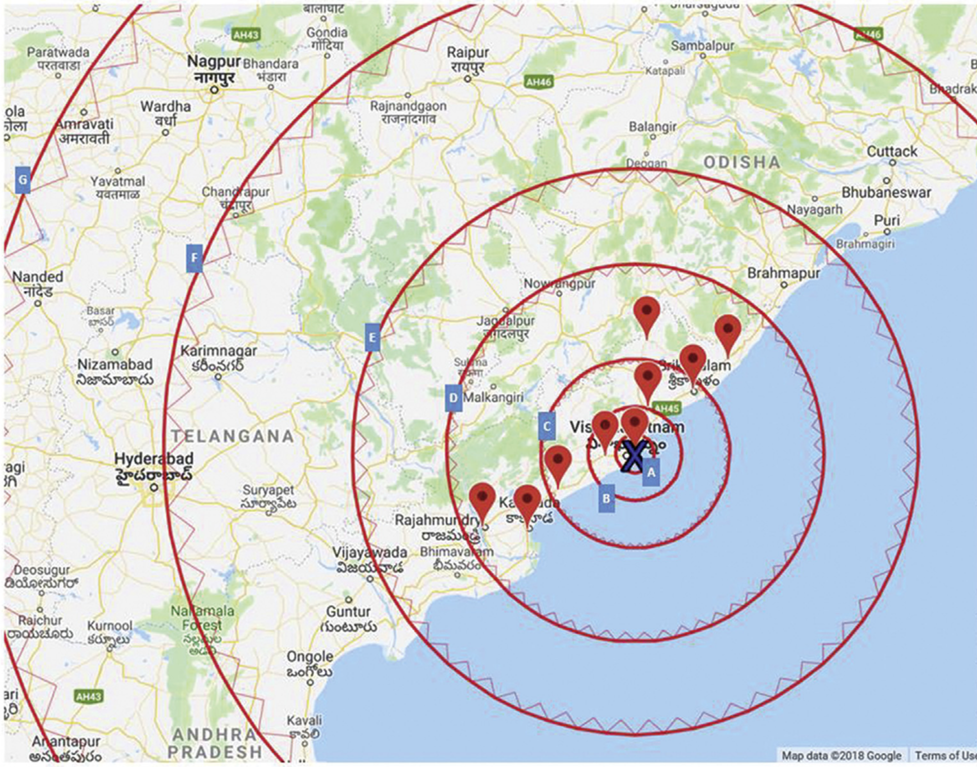
From the [1]Department of Neurosurgery, King George Hospital, Andhra Medical College Visakhapatnam, KGH, Opp KGH OP Gate, Maharani Peta, Visakhapatnam, Andhra Pradesh, India; [2]Department of Anesthesiology & Pain Medicine and [3]Harborview Injury Prevention and Research Center, University of Washington, Seattle, Washington, USA; [4]Department of Neurosurgery, Madras Medical College and Dr. Rai Memorial Medical Centre, Madras Medical College, Park Town, Chennai, Tamil Nadu, India; [5]Division of Neurocritical Care & Trauma, Department of Neurological Science, Christian Medical College, Vellore, Tamil Nadu, India; [6]Department of Neurosurgery, S.M.S Medical College Jaipur, Jawahar Lal Nehru Marg, Gangawal Park, Adarsh Nagar, Jaipur, Rajasthan, India; Departments of [7]Neurosurgery and [8]Epidemiology and Centre for Public Health, National Institute of Mental Health and Neuro Sciences, Bangalore, India; [9]Department of Neurosurgery, Zucker School of Medicine at Hofstra/Northwell, Manhasset, Hempstead, New York, USA; and [10]Department of Pediatric Neurosurgery, University of Central Florida College of Medicine, Orlando, Florida, USA

To whom correspondence should be addressed: Jogi V. Pattisapu, M.D.
[E-mail: Jogi.Pattisapu@UCF.edu; jpattisapu@ped-neurosurgery.com]

Citation: World Neurosurg. X (2019) 2:100020.
https://doi.org/10.1016/j.wnsx.2019.100020

Journal homepage: www.journals.elsevier.com/world-neurosurgery-x

Available online: www.sciencedirect.com



	Radius (km)	Total N=442 %	Direct Admits N=335 %	Transfers N=107 %
A	0-20	28.1	31.9	16.0
B	21-50	22.4	23.3	19.6
C	51-100	24.4	25.1	22.4
D	101-200	21.5	17.0	35.5
E	201-300	0.9	0.6	1.9
F	301-500	1.6	0.9	3.7
G	501-700	1.1	1.2	0.9

Figure 1. Google Maps showing radial distance traveled by 442 of 447 adult patients with traumatic brain injury from injury site to trauma center (King George Hospital, Visakhapatnam, India denoted by *X*). Legend shows distance by transfer status.

and nearly 1 million people remain disabled.[3,4] More information is needed regarding the clinical epidemiology across the severity spectrum and interventions that may improve TBI outcomes in the Indian context.[5,6]

Detailed information on the clinical course, treatment, and outcomes of patients with TBI from India is sparse. Assumptions regarding TBI severity and outcomes derived from U.S. and European cohorts may not be valid in countries like India, even if in-hospital care is comparable.[7,8] We recently reported improved outcomes by adherence to in-hospital indicators of the Brain Trauma Foundation guidelines, but prehospital (PH) data could not be evaluated.[9] Subsequently, a collaboration of Indo-U.S. physicians and scientists was formed to study and improve TBI care and outcomes across India (including PH care). *Lancet Neurology* published a viewpoint introducing this Indo-U.S. collaboration.[9,10]

In 2017, a new effort was initiated at the Andhra Medical College, Visakhapatnam, which is the primary referral teaching hospital (located in a large southeastern coastal city), to study various TBI initiatives and quality improvement processes. This study examined baseline data and discharge outcomes of patients with TBI prior to implementation of the Andhra Pradesh Traumatic Brain Injury Project.

MATERIALS AND METHODS

Study Design, Setting, and Data Sources

We conducted a prospective observational cohort study of adult patients with TBI who received evaluation and treatment between May and October 2017 at King George Hospital (KGH), which is a 1200-bed state government–owned tertiary hospital, from the 6-month observation period between May and October 2017. Data sources were case report forms and medical records, which were developed for this study. Data were entered into a secured web-based data entry system in a de-identified manner for analysis. Clinical decisions were made as per usual care by attending clinicians.

Ethics Committee/Institutional Review Board Approval

KGH and Andhra Medical College Ethics Committee, Visakhapatnam approved this study and allowed waiver of consent.

Organizational Characteristics

Andhra Pradesh has no formal PH emergency trauma system and contracts with a national 108 ambulance service that provides free 24-hour emergency response and transport to nearby hospitals.[10]

Table 1. Organizational Characteristics of Peripheral Network Centers

Organizational Characteristics	Hospital II A	Hospital II B	Hospital III A	Hospital III B	Hospital III C	Hospital III D	Hospital III E	Hospital III F
Number of beds	750	1050	100	200	350	184	100	100
Approximate outpatient visits per day	1200	1500	800	900	900	400	500	400
CT scanners	1	1	1	1	1	No	No	1
Operating rooms	4	14	2	2	2	2	2	1
Emergency department	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ICU	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ICU beds	16	20	6	5	5	14	4	10
24-Hour in-house physician coverage	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Neurosurgical staff	Yes	Yes	No	No	Yes	No	No	No
Other physicians/residents	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Nurses/staff members	200	147	36	48	60	27	23	32
Number of physicians	8	70	1	2	2	10	1	1

CT, computed tomography; ICU, intensive care unit.

KGH is the primary referral hospital (level I trauma center), serves both rural and urban populations, and treats approximately 3000 patients per day from Visakhapatnam and neighboring districts of north coastal Andhra Pradesh, including Vizianagaram, Srikakulam, and East Godavari, and the neighboring states of Chhattisgarh and Orissa.[11] The hospital has 1200 beds, serves an average of 1250 outpatients per day, with 115–130 admissions and 110 emergency cases, and conducts 60–70 surgeries daily. The trauma center has 4 operating rooms (ORs) (2 for surgery and 1 each for neurosurgery and orthopedic surgery) and 2 intensive care units (ICUs), with a dedicated 18-bed neurosurgical ICU. There is 24-hour in-house physician coverage with 2 physicians, 2 attending neurosurgeons, and 2 neurosurgery residents on call.

The KGH emergency department (ED) receives trauma patients directly from the scene of injury and from peripheral in-network and nonnetwork centers. Hospitals participating in this project include level II and level III centers (Figure 1 and Table 1). The level II hospitals are large in-network centers (750–1000 beds) serving 1200–1500 patients per day. Despite the large population they serve, most centers have limited resources. For example, 75% of centers have 1 dedicated trauma computed tomography (CT) scanner, and some have none (and rely on outsourcing to private institutions) and have 1–2 operating rooms. Most (62%) have a maximum of 2 surgeons.

Typical Disposition of Patients with TBI from KGH ED

Patients with Glasgow Coma Scale (GCS) scores of 13–15 (mild TBI) are admitted or discharged based on clinical symptoms (vomiting, headache, or dizziness) and head CT scan findings. Typically, patients are admitted from the ED for persistent symptoms, abnormal head CT scan, or after-hours evaluation despite normal head CT scan because of transport issues or lack of safe local out of hospital observation options. On average, 10–15 patients with TBI are treated and discharged from the ED after TBI each day, mostly with mild TBI and normal head CT scan. Some patients are transferred to the KGH ED for on demand head CT scans from outside hospitals to rule out TBI because of the paucity of CT scanners at peripheral hospitals; patients are discharged home from the ED if imaging is normal. Patients with moderate (GCS score 9–12) and severe TBI (GCS score <9) are admitted from the ED to the ICU, OR, or hospital ward as clinically necessary.

Inclusion Criteria

Eligible participants were adults older than 18 years of age admitted with TBI to the primary referring hospital. *International Classification of Diseases* codes are not clinically used in India and hence were not available for TBI classification. We included subjects with polytrauma and transfers from both in-network and nonnetwork hospitals.

Outcomes

Main outcomes were in-hospital mortality and unfavorable outcomes (Glasgow Outcome Scale score). Discharge Glasgow Outcome Scale scores were collected by trained study personnel and categorized as unfavorable (dead/vegetative state/major impairment) versus favorable (baseline functioning status/minor impairment) outcomes.[12]

Covariates/Factors

We examined the following: 1) patient demographics (age, sex, education level), 2) injury details (mode of injury, bleeding), 3) transport/transfer factors (distance from injury site to trauma center, admission status: direct admit vs. transfer, mode of transport: self, private ambulance, 108 ambulance), 4) PH care (cervical spine immobilized, airway placed), 5) ED admission characteristics (vital signs, GCS score, polytrauma, CT findings),

Table 2. Bivariate Analyses of Demographics, Injury, Transport/Transfer, and Prehospital Characteristics of 447 Adult Patients with Traumatic Brain Injury Admitted to the Tertiary Trauma Center by Discharge Outcomes (dead vs. alive, unfavorable vs. favorable)

Characteristic	Total (N = 447)	Alive (n = 334; 74.7%)	Dead (n = 113; 25.3%)	Favorable (n = 296; 66.2%)	Unfavorable (n = 151; 33.8%)
Demographics					
Age (years)					
18–44	257 (57.5)	200 (59.9)	57 (50.4)	179 (60.5)	78 (51.7)
45–64	144 (32.2)	105 (31.4)	39 (34.5)	92 (31.1)	52 (34.4)
≥65	46 (10.3)	29 (8.7)	17 (15.0)	25 (8.5)	21 (13.9)
Sex					
Male	363 (81.2)	272 (81.4)	91 (80.5)	242 (81.8)	121 (80.1)
Education level					
<Primary	116 (26.0)	83 (24.9)	33 (29.2)	76 (25.7)	40 (26.5)
Primary	153 (34.2)	116 (34.7)	37 (32.7)	101 (34.1)	52 (34.4)
Secondary	110 (24.6)	85 (25.5)	25 (22.1)	75 (25.3)	35 (23.2)
College/higher	68 (15.2)	50 (14.9)	18 (15.9)	44 (14.9)	24 (15.9)
Injury characteristics					
Mode of injury					
Road traffic accident	215 (48.1)	148 (44.3)	67 (59.3)	128 (43.2)	87 (57.6)
Fall	208 (46.5)	167 (50.0)	41 (36.3)	152 (51.4)	56 (37.1)
Assault	11 (2.5)	6 (1.8)	5 (4.4)	6 (2.0)	5 (3.3)
Other	13 (2.9)	13 (3.9)	0 (0.0)	10 (3.4)	3 (2.0)
Transport/transfer characteristics					
Distance from injury site to trauma center (km) (n = 442*), median (IQR)	50.0 (18.0–102.0)	50.0 (18.0–104.0)	50.0 (17.0–93.0)	50.0 (18.0–104.0)	52.0 (18.0–90.0)
Admission status					
Direct admits	340 (76.1)	252 (75.5)	88 (77.9)	220 (74.3)	120 (79.5)
Transfers	107 (23.9)	82 (24.5)	25 (22.1)	76 (25.7)	31 (20.5)
Mode of transport					
Self	243 (54.3)	181 (54.2)	62 (54.9)	157 (53.0)	86 (57.0)
Private ambulance	116 (26.0)	86 (25.7)	30 (26.5)	80 (27.0)	36 (23.8)
108 ambulance	88 (19.7)	67 (20.1)	21 (18.6)	59 (19.9)	29 (19.2)
Prehospital characteristics					
Cervical spine immobilized	31 (6.9)	24 (7.2)	7 (6.2)	21 (7.1)	10 (6.6)
Airway placed†	49 (11.0)	13 (3.9)	36 (31.9)	12 (4.1)	37 (24.5)
Bleeding‡ present	271 (60.6)	179 (53.6)	92 (81.4)	156 (52.7)	115 (76.2)

Values are number of patients (%) or as otherwise indicated.
Favorable, minor impairment or baseline functioning status; Unfavorable, dead or vegetative state or major impairment; IQR, interquartile range.
*Distance from injury site to trauma center (km) was out of 442 patients (335 direct admits and 107 transfers) because injury address was missing in 5 patients (1.1%).
†Of 447 patients, 49 (11%) underwent tracheal intubation prior to King George Hospital admission.
‡Bleeding includes scalp and facial bleeds.

Table 3. Bivariate Analyses of Emergency Department and Outcome Characteristics of 447 Adult Patients with Traumatic Brain Injury Admitted to the Tertiary Trauma Center by Discharge Outcomes (dead vs. alive, unfavorable vs. favorable)

Characteristic	Total (N = 447)	Alive (n = 334; 74.7%)	Dead (n = 113; 25.3%)	Favorable (n = 296; 66.2%)	Unfavorable (n = 151; 33.8%)
ED admission characteristics					
Caregiver present in ED	400 (89.5)	298 (89.2)	102 (90.3)	263 (88.9)	137 (90.7)
Heart rate	79.5 ± 10.6	78.6 ± 9.2	82.2 ± 13.7	78.9 ± 9.3	80.6 ± 12.7
Blood pressure systolic	122.0 ± 23.9	121.4 ± 21.7	123.9 ± 29.5	121.8 ± 22.1	122.5 ± 27.1
Blood pressure diastolic	79.7 ± 13.2	79.6 ± 11.8	80.0 ± 16.7	79.7 ± 11.9	79.8 ± 15.4
Respiratory rate	21.3 ± 7.0	20.8 ± 4.7	22.7 ± 11.1	20.8 ± 4.8	22.1 ± 9.8
Oxygen saturation	95.5 ± 4.9	95.9 ± 3.2	94.4 ± 7.9	96.0 ± 3.2	94.6 ± 7.0
Admission GCS total score					
3	41 (9.2)	8 (2.4)	33 (29.2)	8 (2.7)	33 (21.86)
4	28 (6.3)	7 (2.1)	21 (18.6)	6 (2.0)	22 (14.6)
5	9 (2.0)	5 (1.5)	4 (3.5)	5 (1.7)	4 (2.7)
6	16 (3.6)	5 (1.5)	11 (9.7)	5 (1.7)	11 (7.3)
7	21 (4.7)	10 (3.0)	11 (9.7)	8 (2.7)	13 (8.6)
8	30 (6.7)	18 (5.4)	12 (10.6)	15 (5.1)	15 (9.9)
9	38 (8.5)	31 (9.3)	7 (6.2)	28 (9.5)	10 (6.6)
10	30 (6.7)	25 (7.5)	5 (4.4)	23 (7.8)	7 (4.6)
11	28 (6.3)	28 (8.4)	0 (0.0)	24 (8.1)	4 (2.7)
12	38 (8.5)	37 (11.1)	1 (0.9)	29 (9.8)	9 (6.0)
13	26 (5.8)	24 (7.2)	2 (1.8)	21 (7.1)	5 (3.3)
14	17 (3.8)	15 (4.5)	2 (1.8)	13 (4.4)	4 (2.7)
15	125 (28.0)	121 (36.2)	4 (3.5)	111 (37.5)	14 (9.3)
Admission GCS motor score					
1	41 (9.2)	9 (2.7)	32 (28.3)	9 (3.0)	32 (21.2)
2	31 (6.9)	9 (2.7)	22 (19.5)	8 (2.7)	23 (15.2)
3	10 (2.2)	6 (1.8)	4 (3.5)	6 (2.0)	4 (2.7)
4	70 (15.7)	43 (12.9)	27 (23.9)	36 (12.2)	34 (22.5)
5	133 (29.8)	114 (34.1)	19 (16.8)	100 (33.8)	33 (21.9)
6	162 (36.2)	153 (45.8)	9 (8.0)	137 (46.3)	25 (16.6)
Pupils on arrival					
Both reactive	357 (79.9)	300 (89.8)	57 (50.4)	267 (90.2)	90 (59.6)
Only one reactive	22 (4.9)	10 (3.0)	12 (10.6)	9 (3.0)	13 (8.6)
Both nonreactive	58 (13.0)	15 (4.5)	43 (38.1)	13 (4.4)	45 (29.8)
Could not assess	10 (2.2)	9 (2.7)	1 (0.9)	7 (2.4)	3 (2.0)

Values are mean ± SD or number of patients (%).
Favorable, minor impairment or baseline functioning status; Unfavorable, dead or vegetative state or major impairment; ED, emergency department; GCS, Glasgow Coma Scale; CT, computed tomography; ICU, intensive care unit; OR, operating room.
*ICU length of stay (days) is calculated for 328 patients because only 328 patients stayed in the ICU.

Continues

Table 3. Continued

Characteristic	Total (N = 447)	Alive (n = 334; 74.7%)	Dead (n = 113; 25.3%)	Favorable (n = 296; 66.2%)	Unfavorable (n = 151; 33.8%)
Polytrauma	50 (11.2)	35 (10.5)	15 (13.3)	31 (10.5)	19 (12.6)
Head CT findings					
Epidural hematoma	81 (18.1)	71 (21.3)	10 (8.9)	56 (18.9)	25 (16.6)
Subdural hematoma	128 (28.6)	98 (29.3)	30 (26.6)	86 (29.1)	42 (27.8)
Subarachnoid hemorrhage	111 (24.8)	65 (19.5)	46 (40.7)	54 (18.2)	57 (37.8)
Intraventricular hemorrhage	9 (2.0)	2 (0.6)	7 (6.2)	1 (0.3)	8 (5.3)
Intracerebral hemorrhage/contusion	197 (44.1)	139 (41.6)	58 (51.3)	104 (35.1)	93 (61.6)
Diffuse axonal injury	51 (11.4)	14 (4.2)	37 (32.7)	11 (3.7)	40 (26.5)
Outcome characteristics					
ICU length of stay (days) (n = 328*)	3.7 ± 1.9	4.2 ± 1.1	2.9 ± 2.7	4.2 ± 1.1	3.1 ± 2.5
Hospital length of stay (days)	11.5 ± 6.6	14.3 ± 4.9	3.4 ± 4.0	14.3 ± 4.9	6.1 ± 6.4
ED disposition					
To OR	143 (32.0)	142 (42.5)	1 (0.9)	118 (39.9)	25 (16.6)
To ICU	185 (41.4)	73 (21.9)	112 (99.1)	68 (23.0)	117 (77.5)
To ward	119 (26.6)	119 (35.6)	0 (0.0)	110 (37.2)	9 (6.0)

Values are mean ± SD or number of patients (%).
Favorable, minor impairment or baseline functioning status; Unfavorable, dead or vegetative state or major impairment; ED, emergency department; GCS, Glasgow Coma Scale; CT, computed tomography; ICU, intensive care unit; OR, operating room.
*ICU length of stay (days) is calculated for 328 patients because only 328 patients stayed in the ICU.

and 6) outcome characteristics (ED disposition, death, disability, and ICU/hospital length of stay [LOS]). We considered both nonmodifiable (patient demographics, injury characteristics) and modifiable PH (transport/transfer characteristics, PH care) and ED factors potentially associated with discharge outcomes.

Statistical Analyses

Baseline, clinical, and outcome characteristics were examined in bivariate analyses by discharge outcomes (in-hospital mortality and unfavorable outcomes) and described using frequencies and proportions. Risk factors in each nonmodifiable and modifiable PH and ED category for the whole cohort were examined using modified Poisson regression with robust error variance to yield relative risk estimates and 95% confidence intervals (CIs).[13,14] Factors that were significantly associated with the outcomes in bivariate models were entered into a multivariable model for the respective outcomes, taking into account any co-linearity among risk factors. For example, because GCS motor score and pupils on arrival were collinear, we considered one of them. We also examined factors in each category (nonmodifiable and modifiable PH and ED) associated with discharge outcomes among the subset of patients with severe TBI; mild or moderate TBI were excluded because of few deaths/unfavorable outcomes. Adjusted attributable risk percent (AR%) estimates were used to estimate the outcome burdens associated with significant and potentially modifiable factors. Because missing data were rare for variables used in the regression models (only 1.1% missingness in the distance from injury site variable), we performed a complete case analysis. Descriptive statistics (percentage, proportions) were used to report changes in the presence of outcome factors and injury and transport characteristics over the 6-month study period. Data were analyzed using Stata 14 (StataCorp LLC, College Station, Texas, USA).

RESULTS

Data Quality

Four hundred and forty-seven patients were enrolled. Complete data were available for all variables except distance traveled to KGH from injury site, which was available for 442 patients (335 direct admits and 107 transfers); injury site addresses were missing in 5 patients (1.1%).

Cohort Characteristics

The mean age of the cohort was 41.2 ± 15.2 years (Tables 2 and 3). Most (58%) were 18–44 years of age, and 60% received only primary education. Most (81%) were men and had isolated TBI (89%) that resulted from a road traffic accident or fall (95%), and less commonly (2.5%) from assault. Nearly half the cohort had injury from a road traffic accident (48%), and approximately 47% had a fall that included struck by vehicle and falls in the domestic environment. A similar number of patients had mild (38%), moderate (30%), and severe (32%) TBI. Most patients (54.7%) were not transported by an ambulance. Bleeding

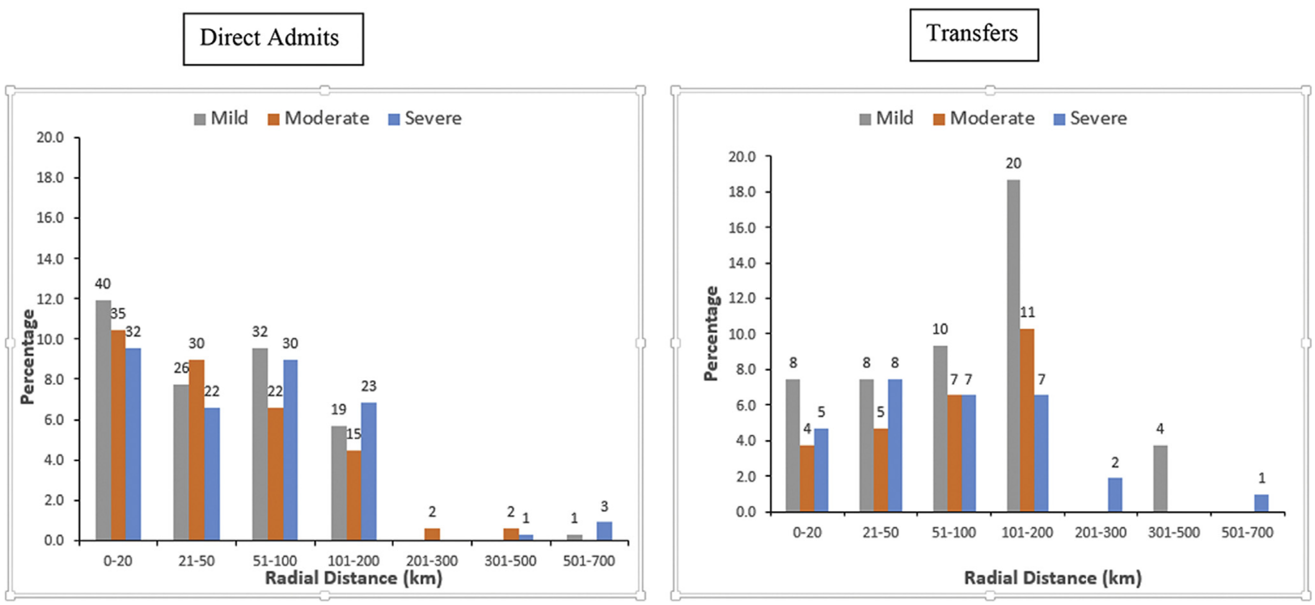


Figure 2. Radial distance (km) traveled from injury site to trauma center (King George Hospital) by 442 adult patients with traumatic brain injury (TBI) by transfer status and by TBI severity. Admission Glasgow Coma Scale (GCS) score: mild TBI = GCS score 13–15, moderate TBI = GCS score 9–12, and severe TBI = GCS score <9. Of 442 patients (98.9% of the total cohort of 447 patients with distance data), 168 (38%) had mild, 133 (30%) had moderate, and 141 (32%) had severe TBI. Of 335 direct admits, 118 (35%) had mild, 106 (32%) had moderate, and 111 (33%) had severe TBI. Of 107 transfers, 50 (47%) had mild, 27 (25%) had moderate, and 30 (28%) had severe TBI.

occurred in 271 of 447 patients (61%), of which 102 patients (23%) had scalp or facial bleeding. Respiratory distress occurred in 11%.

Travel Characteristics

Of the patients, 76% were admitted directly from the injury site to KGH. Figure 1 shows radial distances from the 8 peripheral network centers to KGH and travel distances. Nearly 50% of patients traveled more than 50 km from injury site to KGH; 25% traveled more than 100 km.

Among the 335 direct admits, 45% traveled more than 50 km, and nearly 20% traveled more than 100 km despite peripheral network and nonnetwork centers being available en route (Figure 1). Figure 2A shows radial distance traveled by the 335 patients who were directly admitted to KGH by TBI severity. Nearly two thirds of direct admits had moderate or severe TBI (217/335 [65%]), of whom 45% (98/217) traveled more than 50 km. Many patients with mild TBI (118/335 [35%]) were directly transported to KGH, and 44% (52/118) traveled more than 50 km (Figure 2).

Nearly a quarter (107/447 [24%]) received primary care at a peripheral network or nonnetwork center and were subsequently transferred to KGH. Of the 107 transfers, 42% traveled more than 100 km (Figure 1). Nearly half of transferred patients (50/107 [47%]) had mild TBI but nevertheless traveled a median distance of 86 km (interquartile range [IQR], 47–121), and 32% (34/107) had mild TBI and traveled more than 50 km (Figure 2).

TBI Severity and Transfer Status

Of the whole cohort, 168 (38%) had mild (median GCS admit score 15; IQR, 14–15), 134 (30%) had moderate (median GCS admit score 10; IQR, 9–12), and 145 (32%) had severe (median GCS admit score 5; IQR, 3–7) TBI. Most with severe TBI (90/145 [62%]) had road traffic accidents, whereas more than half with mild TBI (94/168 [56%]) sustained falls ($P < 0.001$).

More patients with severe TBI (109/145 [75%]) had PH bleeding than patients with moderate (85/134 [63%]) or mild TBI (77/168 [46%]) ($P < 0.001$). Less than a third of patients with severe TBI (45/145 [31%]) received PH airway management prior to KGH evaluation. Mean ICU LOSs for patients with moderate and severe TBI were 4.3 ± 1.5 and 3.0 ± 2.3 days, respectively.

Less than a quarter of patients with TBI (17% with mild TBI, 23% with moderate TBI, and 19% with severe TBI) were transported by 108 ambulance. Ambulance service was used more often for interfacility transfers than direct admits to KGH (28% vs. 17%, respectively; $P < 0.001$). Of the transfers who used 108 ambulance, 70% (21/30) had moderate or severe TBI. PH bleeding (scalp and facial bleeding) occurred in more than two thirds of transferred patients (73/107 [68%]) who presented to KGH; of these, 44% (32/73) had mild TBI. Family members were less likely to be present on ED admission among transfers than direct admits (81% vs. 92%, respectively; $P = 0.002$).

Overall, 94% of the total cohort (420/447) received a head CT scan, of whom 26% died (110/420) and 35% (145/420) had unfavorable discharge outcomes. Among patients examined with a

Table 4. Multivariable Analyses of Factors Associated with Outcomes (in-hospital mortality and unfavorable outcomes) in 447 Adult Patients with Traumatic Brain Injury Admitted to the Tertiary Trauma Center

Factors	In-Hospital Death (n = 113; 25.3%)	Unfavorable Outcomes (n = 151; 33.8%)
Mode of injury		
Road traffic accident	Reference	-
Fall	0.88 (0.66—1.16)	-
Assault	2.19 (1.21—3.95)	-
Admission GCS motor score		
1	Reference	Reference
2	0.91 (0.67—1.24)	0.92 (0.67—1.28)
3	0.61 (0.27—1.38)	0.54 (0.26—1.12)
4	0.67 (0.47—0.96)	0.74 (0.51—1.06)
5	0.28 (0.17—0.47)	0.40 (0.26—0.59)
6	0.14 (0.07—0.30)	0.35 (0.22—0.56)
Head CT findings		
Subarachnoid hemorrhage present	1.37 (1.05—1.78)	-
Diffuse axonal injury present	2.00 (1.51—2.66)	2.39 (1.80—3.18)
Intracerebral hemorrhage/contusion	-	2.40 (1.86—3.10)
Intraventricular hemorrhage	-	1.63 (1.13—2.33)
Prehospital		
Bleeding* present	1.56 (1.05—2.31)	1.60 (1.18—2.17)

Values are adjusted relative risk (95% confidence interval).
Unfavorable, dead or vegetative state or major impairment; GCS, Glasgow Coma Scale; CT, computed tomography.
*Bleeding includes scalp and facial bleeds.

head CT scan, 99% had some abnormality noted on the head CT scan.

Outcomes

After admission, more than two thirds of patients (n = 328 [73%]) received ICU care. The mean ICU LOS was 3.7 ±1.9 days, and the in-hospital LOS was 11.5 ± 6.6 days. One hundred and thirteen patients (25.3%) died in-hospital, and including deaths, 151 (34%) had an unfavorable outcome. In-hospital mortality increased with TBI severity (mild: 4.8% vs. moderate: 9.7% vs. severe: 63.5%; $P < 0.001$).

Factors Associated with In-Hospital Mortality

For the entire cohort of 447 patients, higher admission GCS motor score was associated with lower in-hospital mortality (GCS motor score 4: adjusted relative risk [aRR], 0.67; 95% CI, 0.47—0.96; GCS motor score 5: aRR, 0.28; 95% CI, 0.17—0.47; GCS motor score 6: aRR, 0.14; 95% CI, 0.07—0.30) (Table 4). The presence of subarachnoid hemorrhage and diffuse axonal injury were associated with higher in-hospital mortality (aRR, 1.37; 95% CI, 1.05—1.78 and aRR, 2.00; 95% CI, 1.51—2.66, respectively). Assault, although infrequently reported, was associated with higher in-hospital mortality (aRR, 2.19; 95% CI, 1.21—3.95).

The presence of PH bleeding (scalp and facial) was associated with higher in-hospital mortality (aRR, 1.56; 95% CI, 1.05—2.31) (Table 4). After adjusting for risk factors, 36% of deaths (AR%, 35.9%; 95% CI, 9.2%—55.4%) among those with PH bleeding were attributed to PH bleeding.

Factors associated with in-hospital mortality among the 145 patients with severe TBI were bilateral nonreactive pupils (aRR, 1.33; 95% CI, 1.03—1.73) and diffuse axonal injury (aRR, 1.36; 95% CI, 1.09—1.69) (Table 5).

Factors Associated with Unfavorable Discharge Outcomes

For the entire cohort, higher admission GCS motor score was associated with lower in-hospital mortality (GCS score motor 5: aRR, 0.39; 95% CI, 0.26—0.58; GCS score motor 6: aRR, 0.34; 95% CI, 0.21—0.55) (Table 4). The likelihood of unfavorable discharge outcomes was higher with diffuse axonal injury (aRR, 2.39; 95% CI, 1.80—3.18), intracerebral hemorrhage/contusion (aRR, 2.40; 95% CI, 1.86—3.10), and intraventricular hemorrhage (aRR, 1.63; 95% CI, 1.13—2.33) identified on initial CT scan.

Patients with PH bleeding had more unfavorable outcome (aRR, 1.60; 95% CI, 1.18—2.17) (Table 4). Overall, 37% of unfavorable discharge outcomes (AR%, 37.4%; 95% CI, 17.9%—52.0%)

Table 5. Multivariable analyses of Factors Associated with Outcomes (in-hospital mortality and unfavorable outcomes) in 145 Adult Patients with Severe Traumatic Brain Injury Admitted to the Tertiary Trauma Center

Factors	In-Hospital Death (n = 92; 63.4%)	Unfavorable Outcomes (n = 98; 67.6%)
Pupils on arrival		
Both reactive	Reference	Reference
Only one reactive	1.24 (0.86—1.81)	1.08 (0.73—1.59)
Both nonreactive	1.33 (1.03—1.73)	1.32 (1.05—1.67)
Could not assess	0.36 (0.08—1.72)	0.66 (0.27—1.62)
Head CT findings		
Diffuse axonal injury	1.36 (1.09—1.69)	1.33 (1.04—1.70)
Intracerebral hemorrhage/contusion	-	1.40 (1.11—1.77)
Prehospital		
Respiratory distress	-	1.23 (1.00—1.51)

Values are adjusted relative risk (95% confidence interval).
Unfavorable, dead or vegetative state or major impairment; CT, computed tomography.

among those with PH bleeding were attributed to PH bleeding after adjusting for risk factors.

Among 145 patients with severe TBI, unfavorable discharge outcomes were associated with bilateral nonreactive pupils (aRR, 1.32; 95% CI, 1.05—1.67), diffuse axonal injury (aRR, 1.33; 95% CI, 1.04—1.70), and intracerebral hemorrhage/contusion (aRR, 1.40; 95% CI, 1.11—1.77) (Table 5). PH respiratory distress was associated with unfavorable discharge outcomes (aRR, 1.23; 95% CI, 1.00—1.51) (Table 5). Nearly 19% of unfavorable discharge outcomes (AR%, 18.7%; 95% CI, 0%—33.8%) among those with respiratory distress were attributed to PH respiratory distress after adjusting for risk factors.

Observed Changes Over the Study Period

Over the 6-month study period, PH bleeding and respiratory distress increased by 31% and 59%, respectively. The proportion of patients with mild TBI admitted to KGH increased by 61% and the proportion of transfers increased by 620%.

DISCUSSION

In this large prospective observational study from India, we report on PH care of patients with TBI who were admitted to KGH before implementation of the Andhra Pradesh Traumatic Brain Injury Project, and identify modifiable PH factors associated with favorable discharge outcomes. Key findings are that 1) nearly 40% had mild TBI but many were transferred to KGH ED, bypassing peripheral centers; 2) most patients were not transported by ambulance, and few patients were transported by 108 ambulance service, regardless of TBI severity; 3) few patients received PH cervical spine immobilization and airway management when needed; 4) most had PH facial/scalp bleeding and respiratory distress associated with unfavorable outcomes; 5) assault-related TBI was associated with a high in-hospital mortality; and 6) mortality rates across the spectrum of TBI were very high. These results provide the first detailed account of patients with TBI across the severity spectrum and of the quality of PH care and TBI outcomes. Findings suggest an urgent system-wide need for improvement in the recognition and treatment of PH bleeding and airway management early after TBI and the need for education and training to local hospitals and PH personnel with a focus on PH communication, airway management, and bleeding control. These factors will be addressed by the implementation of the Andhra Pradesh Traumatic Brain Injury Project.

The 2015 Global Burden of Disease project reports road traffic accidents as among the top 10 causes of worldwide mortality.[15] Many of these patients have TBI.[5] As this study shows, although the proportion with mild TBI equaled those with moderate and severe TBI, the proportion of patients using an ambulance system and the distance traveled by TBI severity was equivalent. The large TBI burden, scarcity or unpredictability of local human and technical resources, and the lack of a formal PH system are responsible for the great distances that patients with mild TBI travel despite the presence of nearby in-network hospitals. Although we cannot claim that fewer patients with mild TBI should not use ambulances, less than optimal availability of adequately staffed ambulances along with their need, especially for the care of patients with severe TBI, results in suboptimal triage and care of patients who are more severely injured. The high mortality rate across the TBI spectrum clearly illustrates that the PH system needs to be improved.

This study identifies unmet needs regarding PH airway management and hemodynamic stabilization. The fact that PH bleeding resulting from the scalp and PH respiratory distress were common, and were associated with a 1.5-fold higher mortality and a 1.2-fold worse discharge outcome, respectively, suggest an important opportunity for investments in education and training to treat scalp wounds both during PH care and at peripheral hospitals. Adequate control of scalp bleeding early after TBI may save lives and result in transfers only of those patients at risk of more serious TBI, especially because a large number of patients with TBI travel large distances prior to arrival at KGH.[16] Because PH respiratory distress was also associated with poor outcomes in severe TBI, and 40% of poor outcomes were attributed to respiratory distress, another area of focus for PH education and training should be on PH airway management.[17,18] This is important especially because few patients with severe TBI received PH care with airway management prior to KGH admission.

Few patients in our study received PH cervical spine immobilization. However, we did not find a relationship between cervical spine immobilization and outcomes. One reason for its decreased use in the PH setting in India, despite routine use in North America, may be because of lack of clarity around benefits from its routine use across the TBI spectrum in this setting.[19-22] Other reasons may include inadequate resources in terms of trained personnel, equipment, and emergency medical response systems in India.

Road traffic accidents and falls were the most common causes of TBI and elucidate the relationship between mechanism and TBI severity. The World Health Organization suggests that fatalities because of road traffic accidents are on the rise in India and is one of the 3 leading causes of deaths from injuries globally.[2] Although our study does not show an association between road traffic accidents or falls and discharge outcomes, we see a rising trend compared with our previous India study[9] in adults with TBI because of road traffic accidents (34% vs. 48%) and falls that include struck by vehicle (41% vs. 47%). A higher number of vehicles on the road combined with a lack of infrastructure, increased drunk and distracted driving with increased use of mobile phones, and lack of effective law enforcement may be some reasons that explain this trend and calls for urgent attention to improve road safety for both drivers and pedestrians.[23,24]

Although assault accounted for less than 3% of the mode of injury, there was an association with in-hospital death. Previous studies from low- to middle-income countries have reported assaults to be the third most common cause of TBI, accounting for 6%−10% of TBIs and approximately 6% of TBI-related deaths.[3,4,8,25-27] These patterns present an opportunity to adopt a public health approach to injury prevention to reduce TBI incidence across the severity spectrum.

The number of patients admitted to KGH with TBI remained relatively constant over the 6-month observation period, but PH bleeding and PH respiratory distress increased significantly. Reasons for this observed association may be because of the fewer numbers of ambulances, ambulances did not have sufficient numbers or adequately trained PH personnel, or ambulances were being used as transport vehicles. Additionally, most patients were transported by self (caregiver), which meant no PH care was provided to these patients. Another explanation may be that bleeding and respiratory distress were better documented as data collection became more robust.[2,28] The Andhra Pradesh Traumatic Brain Injury Project aims to purchase and provide more ambulances and also to provide education and training of PH personnel in basic life support skills with a focus on PH bleeding control and airway management. If successfully adopted, the recently developed Indian TBI guidelines may help improve PH TBI care and outcomes.[29]

Limitations

This was a single-center study of patients with TBI. We did not collect data on type of job for this study, which may be important in that it may indicate the socioeconomic status or may be related to the mechanism of injury and may be useful for future studies. Analyses on PH factors were limited to those that were recorded, and treatments at referring hospitals were not available. We did not have data on the number, availability, equipment, and personnel of the national 108 ambulance or private ambulance services. Therefore, we are unable to comment on the quality of emergency medical systems transporting patients to KGH. We did not examine patients who were evaluated, treated, and discharged from the KGH ED or those who did not receive neurosurgical evaluation for TBI. We did not have postdischarge outcomes.

Strengths

Although we did not perform a multicenter study for this purpose, we collected high-quality prospective data from the trauma center, most patients had isolated TBI, and our data address TBI across the severity spectrum. We provide new and detailed information on travel distance from injury to a large, tertiary trauma system in a developing country. Importantly, for the first time, we have quantified the magnitude of the association between PH factors and outcomes, and have identified modifiable early factors that can save lives by better triage, skill building, and education and training of PH personnel in a study from a low- to middle-income country with a large TBI burden.

CONCLUSIONS

We present results of the largest prospective study of PH care and TBI outcomes from a low- to middle-income country. Patients with mild TBI received care far away from scene of injury, and few patients received PH airway management, hemorrhage control, and cervical spine immobilization when needed. PH bleeding and respiratory distress were common and were associated with poor outcomes. There is an urgent need to achieve appropriate triage and train PH providers and transferring hospitals to provide timely control of bleeding and establish airway control to improve trauma care and outcomes in the Indian context. These findings are pertinent not just to India but to all low- to middle-income countries.

ACKNOWLEDGMENTS

The authors thank S. J. Mooney, PhD, who provided thoughtful methodologic review and feedback on the manuscript.

REFERENCES

1. Dewan MC, Rattani A, Gupta S, et al. Estimating the global incidence of traumatic brain injury. *J Neurosurg*. 2018:1-18.

2. World Health Organization. Violence and injury prevention: injuries and violence: the facts. 2017. Available at: http://www.who.int/violence_injury_prevention/key_facts/en/. Accessed July 1, 2017.

3. Gururaj G. Epidemiology of traumatic brain injuries: Indian scenario. *Neurol Res*. 2002;24:24-28.

4. Shekhar C, Gupta LN, Premsagar IC, Sinha M, Kishore J. An epidemiological study of traumatic brain injury cases in a trauma centre of New Delhi (India). *J Emerg Trauma Shock*. 2015;8:131-139.

5. Agrawal A, Galwankar S, Kapil V, et al. Epidemiology and clinical characteristics of traumatic brain injuries in a rural setting in Maharashtra, India. 2007-2009. *Int J Crit Illn Inj Sci*. 2012;2:167-171.

6. Kamal VK, Agrawal D, Pandey RM. Epidemiology, clinical characteristics and outcomes of traumatic brain injury: evidences from integrated level 1 trauma center in India. *J Neurosci Rural Pract*. 2016;7:515-525.

7. Chiu WT, LaPorte RE, Gururaj G, et al. Head injuries in developing countries neurotrauma. In: Valadka AB, Narayan RK, eds. *Neurotrauma*. New York, NY: McGraw Hill; 1996:905-912.

8. RK VAaN. Emergency room management of the head-injured patient. In: Narayan RK WJaP, JT, ed. *Neurotrauma*. New York, NY: McGraw Hill; 1996:119-136.

9. Gupta D, Sharma D, Kannan N, et al. Guideline adherence and outcomes in severe adult traumatic brain injury for the CHIRAG (Collaborative Head Injury and Guidelines) study. *World Neurosurg*. 2016;89:169-179.

10. Sriram VM, Gururaj G, Hyder AA. Public-private implementation of integrated emergency response services: case study of GVK Emergency Management and Research Institute in Karnataka, India. *Surgery*. 2017;162:S63-S76.

11. VizagInfo. King George Hospitals, Visakhapatnam. 2018. Available at: http://www.vizaginfo.com/others/kgh.htm. Accessed August 10, 2018.

12. Jennett B, Teasdale G, Braakman R, Minderhoud J, Knill-Jones R. Predicting outcome in individual patients after severe head injury. *Lancet*. 1976;1:1031-1034.

13. McNutt L-A, Wu C, Xue X, Hafner JP. Estimating the relative risk in cohort studies and clinical trials of common outcomes. *Am J Epidemiol*. 2003;157:940-943.

14. Zou G. A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol*. 2004;159:702-706.

15. Wang H, Naghavi M, Allen C, et al. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980-2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet*. 2016;388:1459-1544.

16. Hamilton J, Sunter J, Cooper P. Fatal hemorrhage from simple lacerations of the scalp. *Forensic Sci Med Pathol*. 2005;1:267-271.

17. Stiver SI, Manley GT. Prehospital management of traumatic brain injury. *Neurosurg Focus*. 2008;25:E5.

18. Von Elm E, Schoettker P, Henzi I, Osterwalder J, Walder B. Pre-hospital tracheal intubation in patients with traumatic brain injury: systematic review of current evidence. *Br J Anaesth*. 2009;103:371-386.

19. Aleem IS, DeMarco D, Drew B, et al. The burden of spine fractures in India: a prospective multicenter study. *Global Spine J*. 2017;7:325-333.

20. Hauswald M, Ong G, Tandberg D, Omar Z. Out-of-hospital spinal immobilization: its effect on neurologic injury. *Acad Emerg Med*. 1998;5:214-219.

21. McHugh TP, Taylor JP. Unnecessary out-of-hospital use of full spinal immobilization. *Acad Emerg Med*. 1998;5:278-280.

22. Theodore N, Hadley MN, Aarabi B, et al. Prehospital cervical spinal immobilization after trauma. *Neurosurgery*. 2013;72(suppl 2):22-34.

23. World Health Organization. Road traffic injuries. 2018. Available at: https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries. Accessed January 23, 2019.

24. World Health Organization. Violence and injury prevention: global status report on road safety 2018. 2018. Available at: https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/. Accessed January 23, 2019.

25. Hyder AA, Wunderlich CA, Puvanachandra P, Gururaj G, Kobusingye OC. The impact of traumatic brain injuries: a global perspective. *Neurorehabilitation*. 2007;22:341-353.

26. Qureshi JS, Ohm R, Rajala H, et al. Head injury triage in a sub Saharan African urban population. *Int J Surg*. 2013;11:265-269.

27. Umerani MS, Abbas A, Sharif S. Traumatic brain injuries: experience from a tertiary care centre in Pakistan. *Turkish Neurosurg*. 2014;24:19-24.

28. Sikka V, Gautam V, Galwankar S, et al. The 2017 International Joint Working Group white paper by INDUSEM, The Emergency Medicine Association and The Academic College of Emergency Experts on establishing standardized regulations, operational mechanisms, and accreditation pathways for education and care provided by the prehospital emergency medical service systems in India. *J Emerg Trauma Shock*. 2017;10:154.

29. Neurotrauma Society of India, American Association of South Asian Neurosurgeons, American Association of Physicians for Indian Origin. Traumatic Brain Injury: Multi Organizational Consensus Recommendations for India. 2016. Available at: http://ntsi.co.in/wp-content/uploads/2017/11/Version.pdf. Accessed August 11, 2018.

Conflict of interest statement: This work was supported by the State Government of Andhra Pradesh, American Association of Physicians of Indian Origin, Andhra Medical College Alumni of North America, Section on Neurotrauma and Critical Care of the American Association of Neurological Surgeons and Congress of Neurological Surgeons, and American Association of South Asian Neurosurgeons

Received 15 November 2018; accepted 25 January 2019

Citation: World Neurosurg. X (2019) 2:100020.
https://doi.org/10.1016/j.wnsx.2019.100020

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery-x***

Available online: ***www.sciencedirect.com***