



## RESEARCH ARTICLE

**REVISED** Association between traumatic brain injury (TBI) patterns and mortality: a retrospective case-control study  
[version 2; peer review: 2 approved]

Gilbert Koome <sup>1</sup>, Faith Thuita<sup>1</sup>, Thaddaeus Egondi<sup>2</sup>, Martin Atela <sup>3</sup>

<sup>1</sup>School of Public Health, University of Nairobi, Nairobi, 00200, Kenya

<sup>2</sup>Strathmore Institute of Mathematical Sciences, Strathmore University, Nairobi, 00200, Kenya

<sup>3</sup>Peterhouse, University of Cambridge, Cambridge, Cambridge, UK

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### Abstract

**Background:** Low and medium income countries (LMICs) such as Kenya experience nearly three times more cases of traumatic brain injury (TBI) compared to high income countries (HICs). This is primarily exacerbated by weak health systems especially at the pre-hospital care level. Generating local empirical evidence on TBI patterns and its influence on patient mortality outcomes is fundamental in informing the design of trauma-specific emergency medical service (EMS) interventions at the pre-hospital care level. This study determines the influence of TBI patterns and mortality.

**Methods:** This was a case-control study with a sample of 316 TBI patients. Data was abstracted from medical records for the period of January 2017 to March 2019 in three tertiary trauma care facilities in Kenya. Logistic regression was used to assess influence of trauma patterns on TBI mortality, controlling for patient characteristics and other potential confounders.

**Results:** The majority of patients were aged below 40 years (73%) and were male (85%). Road traffic injuries (RTIs) comprised 58% of all forms of trauma. Blunt trauma comprised 71% of the injuries. Trauma mechanism was the only trauma pattern significantly associated with TBI mortality. The risk of dying for patients sustaining RTIs was 2.83 times more likely compared to non-RTI patients [odds ratio (OR) 2.83, 95% confidence interval (CI) 1.62-4.93,  $p=0.001$ ]. The type of transfer to hospital was also significantly associated with mortality outcome, with a public hospital having a two times higher risk of death compared to a private hospital [OR 2.18 95%CI 1.21-3.94,  $p<0.009$ ].

**Conclusion:** Trauma mechanism (RTI vs non-RTI) and type of tertiary facility patients are transferred to (public vs private) are key factors influencing TBI mortality burden. Strengthening local EMS trauma response systems targeting RTIs augmented by adequately resourced and equipped public facilities to provide quality lifesaving

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Approval Status

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1. **Amit Agrawal** , All India Institute of Medical Sciences, Bhopal, Bhopal, India
2. **Peter Kithuka**, Kenyatta University, Nairobi, Kenya

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interventions can reduce the burden of TBIs.

### Keywords

Trauma Patterns, Patient Characteristics, pre-hospital Care, Traumatic Brain Injuries, Trauma mortality

**Corresponding author:** Gilbert Koome ([rithaag@gmail.com](mailto:rithaag@gmail.com))

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**REVISED Amendments from Version 1**

The differences between this version of our article and the previously published version is the deleted literature in page 4 which presented findings on relationship between trauma patterns and mortality outcomes and trauma statistics from high income countries. Most of this literature was already incorporated in the discussion. This was done to make the introduction section short and concise. We included number of TBI cases and controls presented to the facilities in the study period to provide more details on the sampling frame. Information on how the Disease Diagnosis Codes were assigned and used in the study was included in the methodology section in page 5. The nature of injuries included in the study methods were also added which includes fracture of vault of skull; fracture of base of skull; multiple fractures involving skull and facial bones fractures of other skull and facial bones; fracture of skull and facial bones, part unspecified; injury of cranial nerves; crushing injury of skull; crushing injury of other parts of head; crushing injury of head, part unspecified; multiple injuries of head; other specified injuries of head; unspecified injury of head; fractures involving head with neck; crushing injuries involving head with neck and injuries of brain and cranial nerves with injuries of nerves and spinal cord at neck level. The title of Table 1 was revised to indicate the data presented was on study population characteristics versus mortality distribution rather than patient characteristics and mortality outcomes. Use of GCS scores to refer to trauma severity was replaced with TBI severity in the entire document. In the conclusion deductions on effect of type of tertiary facility transfer on mortality outcomes was removed to retain emphasis on association between trauma patterns and TBI mortality.

**Any further responses from the reviewers can be found at the end of the article**

**Abbreviations**

AOR, adjusted odds ratio; CI, confidential interval; CNS, central nervous system; EMS, emergency medical services; GCS, Glasgow Coma Scale; LMIC, low- and medium-income country; RTI, road traffic injury; SE, standard error; TBI, traumatic brain injury; TI, traumatic injury.

**Introduction**

Trauma is a serious global public health problem.<sup>1</sup> Traumatic injuries (TIs) are estimated to account for 10% of all deaths and about 5.8 million deaths annually and at least 6% of Years Lived with Disability (YLD).<sup>2,3</sup> Low and medium-income countries (LMICs) account for about 90% of this global trauma disease burden.<sup>4</sup> Globally, traumatic brain injury (TBI) is the leading form of TI burden.<sup>1</sup> Currently, about 69 million people suffer from TBI annually, mainly from road traffic injuries (RTIs), violence and falls.<sup>7,8</sup> The estimated economic cost of RTIs in Europe is substantially high with an approximate range of 7500-1,200,00 US dollars.<sup>5</sup> Young persons aged less than 40 years are the most affected.<sup>6</sup> In the EU, over 1.5 million people are admitted to hospital for TBI annually, with Austria and Germany reporting about eight times more admissions compared to Portugal and Spain. One study found EU hospital admissions, adjusted for population, to be three times higher compared to the USA.<sup>7</sup> This indicates significant inter-continental TBI burden and trauma system development variations.

LMICs, mainly in Africa, experience about three times more cases of TBIs compared to these high income countries (HICs).<sup>8</sup> This constitutes approximately 80% of the TBI global burden, most cases of which are potentially preventable using quality and effective pre-hospital care emergency medical service (EMS) systems.<sup>4,9</sup> In these countries, TBI remains a growing public health burden concern. There are increasing concerns that EMS at the pre-hospital care level is ineffective and incapable of adequately mitigating increasing number of TBIs requiring critical care interventions.<sup>10</sup> The economic cost of TBIs, such as mortality, morbidity and high hospital bills, has serious economic impact at an individual, household and societal level.<sup>11</sup> For instance, LMICs, mainly in sub-Saharan Africa, lose about four billion United State dollars (US\$) annually due to RTIs, a major cause of TBIs. This is equivalent to 11% of their gross domestic product (GDP).<sup>10,12</sup> In Kenya, the cost of RTIs is estimated at 14 billion Kenya shillings per year.<sup>13</sup>

In Kenya and other LMICs, the greatest proportion of TBI mortality and morbidity burden is attributed to poor access to quality emergency care.<sup>14</sup> In HICs such as America and Europe, about half of such preventable mortality is said to occur at the pre-hospital care level.<sup>15</sup> The proportion and impact is estimated to be three times as high in LMICs.<sup>8</sup> The disproportionately high burden and cost of TBI in Africa and other LMICs are exacerbated by weak health systems, especially at the pre-hospital care level, and limited reliable empirical evidence to inform effective response to the growing trauma burden.<sup>4,16-19</sup>

Ideally, TBI patients are expected to receive quality pre-hospital care, also known as “life-saving interventions” from trained and qualified health professionals before pre-hospital transport and/or reaching a specialized trauma care facility. However, few patients receive this care, with most victims receiving no life-saving interventions due to lack of qualified staff and resourced EMS facilities at this care level.<sup>14</sup> Evidence affirms a lack of a well-coordinated and integrated pre-hospital trauma care system in these settings to respond to growing TBI burden.<sup>20</sup> Thompson *et al.*<sup>21</sup>

described Kenya's EMS for pre-hospital trauma care such as TBIs as fragmented, poorly coordinated and ineffective. Weakness in the health system has been linked to, among others, inadequate resources, staff, leadership, lack of training standard, lack of emergency trauma specialists, lack of effective communication systems and ineffective EMS response systems.<sup>22–24</sup> In Kenya and other LMICs, evidence to support the development of local and adaptive life-saving interventions for averting or reducing growing TBI mortality at pre-hospital care level are grossly lacking.<sup>11,25</sup>

TBI patterns comprise a complementary component of a responsive trauma/injury assessment and response at the pre-hospital care level. For instance, effective EMS response may require responses matched to the specific trauma source, injury type and its severity level.<sup>26</sup> In this study, trauma pattern is defined in three different ways; based on source (RTIs and non-RTI), type of injury (blunt and penetrating) and day of injury (weekday and weekend). Reviews indicate the main cause of TBIs is RTIs, followed by violence and falls.<sup>10,22,27</sup> Blunt trauma has been closely linked to motor vehicle collisions and falls.<sup>38</sup> TBI burden from RTIs has continued to exert pressure on already weak health systems globally due to increasing motorization and lack of effective EMS response systems.<sup>28–31</sup> In Kenya, more than 75% of health facilities' emergency department visits are also due to RTIs.<sup>12</sup>

In Kenya and other low resource countries, preventive public health measures such as road safety measures and laws like using motorcycle helmets and observing road traffic regulations, have been instituted to reduce trauma burden and address some of the identified EMS response weaknesses. These measures seem to have failed to substantially reduce mortality and disability arising from TBIs and other TIs.<sup>17</sup> Understanding TBI patterns and their influence on mortality can provide important insight on occurrence, presentation, diagnosis and alternative interventions for improving patient survival outcomes. The evidence can also offer critical insight in designing locally adaptive and effective responses for the pre-hospital trauma care level. It is with this background that this study aimed to determine the association between TBI patterns and mortality at the pre-hospital care level.

## Methods

### Data abstraction

We conducted a retrospective unmatched case-control study through data abstraction from hospital-based patient records. This study was done in three leading tertiary referral facilities comprising public (Kenyatta National Hospital, KNH) and private (Kikuyu Mission and Mater Misericordiae Hospital) tertiary trauma facilities in Kenya. Out of the over 1243 TBI patients presented to the facilities over the study period, a total of 812 (453 cases and 359 controls) met our eligibility criteria. To select the 812 patient records, patient medical records and files were reviewed and those meeting eligibility criteria sampled using disease diagnosis codes (DCS) assigned by hospital health records and information officers during care delivery to each of the selected patient file based on the in-patient admission files or Emergency Department (ED) registers. The codes are assigned based on the written medical notes (documentation) on patient examination and diagnosis by the clinical care providers. **Table 3** shows the DCS for TBIs used in this study which includes fracture of vault of skull; fracture of base of skull; multiple fractures involving skull and facial bones. Fractures of other skull and facial bones; fracture of skull and facial bones, part unspecified; injury of cranial nerves; crushing injury of skull; crushing injury of other parts of head; crushing injury of head, part unspecified; multiple injuries of head; other specified injuries of head; unspecified injury of head; fractures involving head with neck; crushing injuries involving head with neck and injuries of brain and cranial nerves with injuries of nerves and spinal cord at neck level.

Data was abstracted from 316 TBI patient medical records (consisting of 158 cases and 158 controls) for the period of January 2017 to March 2019 in the three hospitals. Incidence-density sampling was used to sample controls for the cases sampled. A separate list of cases and controls which met the study inclusion criteria were compiled in an excel sheet. A random sample of 158 cases was generated using the excel list for cases followed by a separate list of 158 controls generated from excel list of controls. To mitigate selection bias emanating from sampling many samples or study subjects either public or private tertiary hospital, a proportionate sampling approach was used to allocate 167 (67 controls and 100 cases) to the public and 159 (58 controls and 39 cases) to private facilities comprising 53% and 47% of the sample respectively. Controls for cases were derived from the same facility to mitigate potential bias associated with difference in quality of care in different facilities.

The study sample was calculated using Kelsey's unmatched case control formula.<sup>42</sup> The formula assumptions were as follows, proportion of cases exposed; 0.667, proportion of controls exposed; 0.6 and case-control ratio of 1.0. Cases were patients who had died within 30 days after the trauma while controls were patients who survived for at least 30 days after trauma. Comorbidity was diagnosed in 36% of controls and 39% of cases while history of alcohol use was reported in 22% of the controls and 33% of the cases. Other patient-related characteristics of the controls and cases sampled, which were adjusted for in the logit model used are shown in **Table 1**.

In the study, adult patients aged 18 years and above presented with TBIs based on ICD diagnosis codes in the three selected trauma referral hospitals for the period between January 2017 to March 2019 were included. Immediate death on the scene, patients not transferred to hospitals due to minor injuries, missing data or documentations comprising at least 5% of core data variables) and history of past severe injury were excluded from the study. Immediate deaths on injury scene due to severe injuries presents little opportunity for improving care through life-saving interventions while minor injuries such as bruises presents no major mortality risks. A total of 211 cases were excluded from the study based on these reasons.

During sampling, immediate cases/deaths occurring at the injury scene were excluded due to inability to obtain comprehensive data and the minimal opportunity for providing pre-hospital care or life-saving interventions. Further, patients admitted in lower level facilities for more than 24 hours after injury were excluded due to potential of confounding linked to differences in care quality in the two levels of care delivery, that is, lower and tertiary level facilities. Pediatric trauma may require different critical care response compared to adult trauma, hence exclusion of patients aged less than 18 years to avoid response-specific bias. Patient records with missing information of at least 5% of the abstracted data were also not included in the analysis.

### Variable(s) description

Data abstracted included TBI mortality, that is: whether the patient died or survived; trauma patterns comprising day of injury (Monday/Tuesday/Wednesday/Thursday/Friday/Saturday/Sunday), type of injury (penetrating/blunt) and injury mechanism (RTI/non-RTI such as violence, falls and gunshots); demographic characteristics comprising age (18-29 years/30-39 years/40-49 years/50-59 years/60+ years) and gender (male/female) and vital patient characteristics consisting of Glasgow Coma Scale (GCS) score (severe, moderate and mild), presence of hypoxemia, defined as blood oxygen concentration of less than 90%, (Yes/No), presence of comorbidity (Yes/No), alcohol involvement (Yes/No), patient triage status (not urgent/urgent/emergency) and blood pressure levels (hypertension/elevated/normal). We also collected data on access to pre-hospital care categorized as Yes/No. Access to pre-hospital care was defined as the provision of life-saving interventions by a qualified health professional such as a paramedic, nurse, clinical officer or medical officer. To improve completeness and accuracy, abstracted data were complemented with other pre-hospital care records including ambulance records, referral notes and trauma registries maintained at the Accident and Emergency Departments. For deceased patients, mortality and death notification reports were used to collate information on death which included cause of death, place of death and the patient demographics comprised of age and gender.

### Statistical analysis

For descriptive analysis, we performed bivariate analysis to assess mortality differences among cases and controls, including both individual and trauma pattern characteristics. We used Pearson's chi-square test to determine the association between trauma pattern and mortality outcomes and Student's t-tests to assess differences in mean patient ages. Logistic regression was used to assess association between mortality and trauma patterns adjusting for other predictor variables. To identify possible confounding effects, existence of a 10% difference between unadjusted and unadjusted regression coefficient was used.<sup>43,44</sup> Statistical significance at 0.05 level between exposure and outcome was also taken into account.<sup>43</sup> Using these statistical methods, type of transfer tertiary facility and TBI severity score (GCS) were found to confound TBI mortality, hence they were included in the analysis as control variables. We included access to pre-hospital care as an important control variable in the model. Based on previous studies and other published literature, we also selected patient and injury characteristics that were clinically and substantively (statistically significant at bivariate analysis level) relevant to be included in the adjusted logistic regression model. In this paper, we report the adjusted odds ratio (AOR) for mortality, after controlling for age, gender, TBI severity, presence of hypoxemia, presence of comorbidity, pre-hospital time, type of transfer tertiary facility and access to pre-hospital care. Due to small sample size in some of the age and injury day variable categories, some of the categories were combined in the regression model - age was re-constituted to three categories (18-29 years/30-39 years/40+ years and injury day to two categories (weekday and weekend). Abstracted medical data was analyzed using IBM SPSS statistics software, version 26. A p-value of less than 0.05 was considered statistically significant.

### Ethics statement

Since the study involved de-identified retrospective data abstracted from many patient records - some of whom were deceased - it was difficult to reach and contact all the respondents and obtain informed consent, particularly, the deceased. A waiver of consent for data abstraction was granted by the Kenyatta National Hospital- and University of Nairobi Ethics and Research Committee (KNH-UoN/ERC/FORM/IC05). A research permit was obtained from the National Commission for Science, Technology and Innovation (NACOSTI/P/19/9613/31326). Institutional ethical clearance was also obtained from all the three hospital ethical boards prior to data collection. There is no identification or individual details presented in this article or data thereof. This is in line with the waiver for consent obtained during ethical approval of this study.

## Results

### Descriptive summary

A descriptive summary of study population characteristics and mortality distribution is shown in **Table 1**. The mean age of patients was 34.5 years and there was no significant difference between cases and controls. Eighty-five percent of the patients were males. The distribution of gender was similar in both cases and controls (82% versus 88%). The distribution of blood pressure levels (hypertension, elevated and normal) was the same among cases compared to controls. The number of severely injured patients was significantly higher among cases compared to controls (65% versus 34%). Similarly, the number of patients triaged as non-urgent was significantly higher among cases than controls (30% versus

**Table 1. Study population characteristics summary by mortality distribution.** Statistical significance (Probability (P) values) is shown in asterisks. Number of cases are 158, Controls are 158 and total population are 316 persons. In the table, + means "and above", "<" means less than and ">" means more than. Parenthesis (-) shows range of values while % means percentage.

Variable		TBI mortality distribution			P-value
		Controls (N=158; %)	Cases (N=158; %)	Total (n=316; %)	
Age (mean)		33.89	35.11	34.5	0.552
Age categories	18-29 years	71(45)	64(41)	135(43)	0.876
	30-39 years	46(29)	49(31)	95(30)	
	40-49 years	17(11)	21(13)	38(12)	
	50-59 years	14(9)	12(8)	26(8)	
	60+ years	10(6)	12(8)	22(7)	
Gender	Male	139(88)	129(82)	268(85)	0.158
	Female	19(12)	29(18)	48(15)	
Blood pressure	Hypertension	63(40)	72(46)	135(43)	0.117
	Elevated	36(23)	24(15)	60(19)	
	Normal	55(55)	66(42)	121(38)	
TBI severity (GCS score)	Severe (GCS<9)	54(34)	100(65)	154(49)	0.001***
	Moderate (GCS 9-12)	37(23)	29(18)	66(21)	
	Mild (GCS 13-15)	67(42)	29(18)	96(30)	
Triage status	Not urgent	34(22)	47(30)	81(26)	0.229
	Urgent	50(32)	47(30)	97(31)	
	Emergency	74(47)	64(41)	138(44)	
Hypoxemia	Yes	39(25)	60(38)	99(31)	0.001***
	No	119(75)	98(62)	217(69)	
Comorbidity	Yes	57(36)	66(42)	123(39)	0.356
	No	101(64)	92(58)	193(61)	
Alcohol use	Yes	35(22)	52(33)	87(28)	0.044*
	No	123(78)	106(67)	229(72)	
Pre-hospital time	<3 hours	101(64)	79(50)	180(57)	0.027*
	3-6 hours	24(15)	26(16)	50(16)	
	6+ hours	33(21)	53(34)	86(86)	
Transfer facility	Public	67(42)	100(63)	167(53)	0.001***
	Private	91(58)	58(37)	159(47)	

\*p<0.05.

\*\*\*p<0.001.

GCS, Glasgow Coma Scale.

Source: Author.

22%). However, the number of patients triaged as emergency cases was significantly higher in controls compared to cases (47% versus 41%).

Hypoxemia was present in 31% of the patients. The number of hypoxemic patients was significantly higher in cases compared to controls (25% versus 38%). Turning to comorbidity, 39% of the patients were diagnosed with comorbidity. The distribution of comorbidity was similar among cases and controls (42% versus 36%). The pattern was different among 28% of the patients who had a history of alcohol use. The distribution of patients with a history of alcohol use was significantly higher among cases compared to controls (33% versus 22%). In respect to pre-hospital time, 57% of patients arrived at the tertiary hospital less than three hours after injury. Distribution of pre-hospital time was significantly different in both cases and controls. There were more patients arriving at the tertiary hospital in less than three hours among controls compared to cases (64% versus 50%). Injured patients are transferred from scenes to different tertiary trauma care hospitals for specialized care and management; 53% of patients were transferred to a public tertiary hospital. The number of patients transferred to a public facility was significantly higher among cases compared to controls (63% versus 42%). Around half (56%) of patients received pre-hospital care. The number of patients who accessed pre-hospital care was significantly higher among controls compared to cases (63% versus 49%).

**Trauma patterns**

We examined three types of trauma patterns; trauma mechanisms (RTI and non-RTI causes), type of injury (blunt and penetrating) and injury day (weekday and weekend). A descriptive summary of trauma patterns by mortality distribution is shown in [Table 2](#).

*Trauma mechanisms*

RTIs were the main cause of TBIs (58%) compared to non-RTI causes (42%) which consisted of falls, violence and gunshots ([Figure 1](#)). RTIs and gunshots were the main source of trauma among patients aged 18-29 years, while violence was main source of trauma among patients aged 18-39 years. Motor vehicles (61%) were the main cause of RTIs compared to motorcycles. Trauma caused by gunshots, falls and violence was mainly reported in public places (54%), followed by home (27%) and workplace (18%). TBIs due to RTIs were significantly higher among cases compared to controls (67% versus 49%).

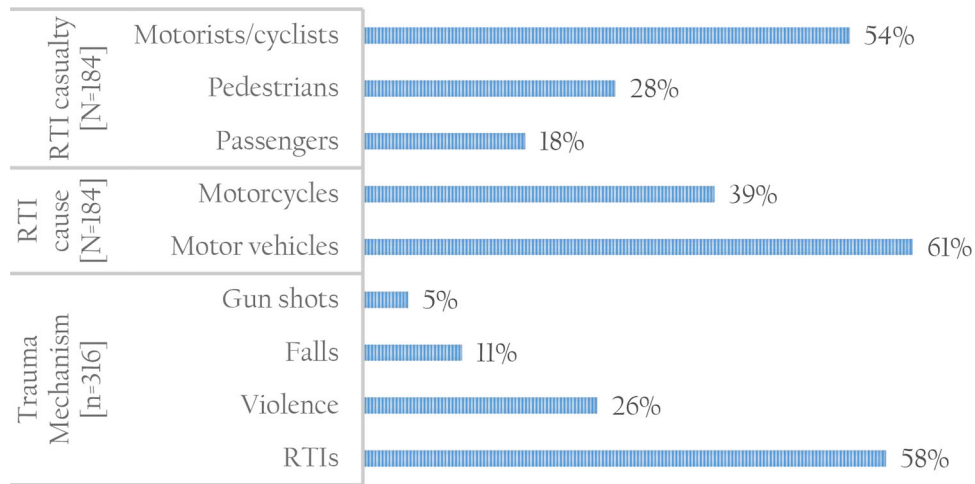
*Type of trauma or injury*

Blunt trauma (71%) was the main form of injury across all forms of trauma. Blunt trauma was mainly caused by RTIs and falls, while penetrating trauma was mainly caused by gunshots and violence-inflicted injuries. The most commonly injured body part was the head (89%) followed by lower extremities as shown in [Figure 2](#). Record review indicated that concussions and contusions were the main form of head injuries attributed to TBIs. Skull fractures and scalp wounds were also frequently reported. Distribution of blunt trauma was significantly higher among cases compared to controls (77% versus 65%).

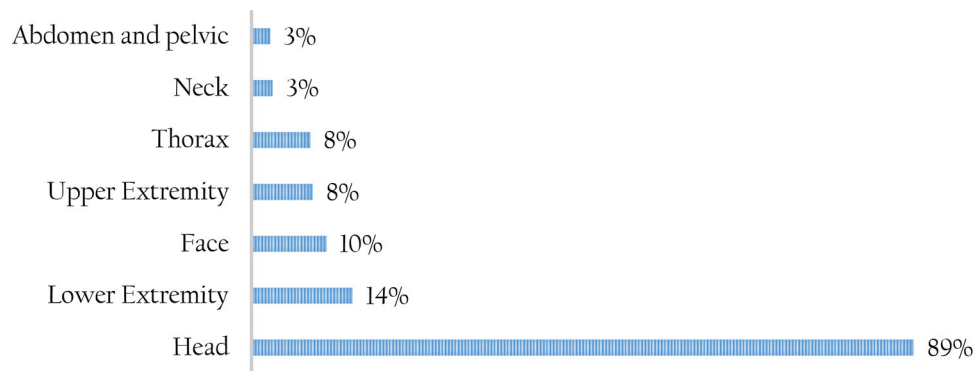
**Table 2. Descriptive summary of trauma patterns by mortality distribution.** Statistical significance (Probability(P) values) is shown in asterisks. Number of cases are 158, Controls are 158 and total population are 316 persons. In the table, Parenthesis (-) shows range of values while % means percentage.

Variable	TBI mortality		Total (n=316; %)	P-value	
	Controls (N=158; %)	Cases (N=158; %)			
Trauma mechanism	RTIs	78(49)	106(67)	184(58)	0.001***
	Non-RTIs	80(51)	52(33)		
Type of trauma	Blunt injury	103(65)	122(77)	225(71)	0.025*
	Penetrating injury	55(35)	36(23)		
Day of injury	Monday	30(19)	18(11)	48(15)	0.286
	Tuesday	18(11)	26(16)		

\*p≤0.05.  
 \*\*\*p≤0.001.  
 RTI, road traffic injury.  
 Source: Author.



**Figure 1. Type of trauma mechanisms and casualties RTI, road traffic injury.** Source: Author.



**Figure 2. Part of the body most commonly injured among the study patients.** Source: Author.

*Injury day*

Cumulatively, 72% of injuries were recorded during weekdays, while 28% were recorded during weekends. The weekday has five days, Monday to Friday, while the weekend has only two days, Saturday and Sunday. The number of injuries was slightly higher on Friday compared to other weekdays. However, distribution of injuries was the same across all weekdays.

**Logistic regression**

We performed logistic regression analysis (53) to examine association between trauma patterns and TBI mortality. Logistic regression results are shown in Table 3. Trauma mechanism was found to be significantly associated with TBI mortality both independently and after adjusting for other patient-related and clinical care variables. RTI patients were 2.83 times more at risk of dying compared to non-RTI patients. Type of injury was found to be significantly associated with TBI mortality independently but this association became insignificant after adjusting for other variables. The risk of dying from blunt trauma was found to be 1.22 times higher compared to penetrating trauma. Further, injury day was not found to be significantly associated with TBI mortality both independently and after adjusting for other variables but the risk of TBI mortality was found to be 0.69 times lower in weekday injuries compared to weekend injuries.

**Discussion**

This study sought to assess the association between trauma patterns and TBI mortality. We found trauma mechanism, in particular, RTIs, to be associated with a higher risk of TBI mortality. Trauma mechanism, mainly TRIs, has been previously studied and associated with all forms of trauma mortality distribution.<sup>33-35</sup> However, these studies did not adjust for access to pre-hospital care and type of trauma care facility, which are shown to be important confounders of mortality risk. Globally, and particularly in sub-Saharan Africa, RTI is a major public health problem contributing to a



**Table 3. Logistic regression model of trauma patterns and TBI mortality.** Statistical significance (Probability (P) values) is shown in asterisks. Number of cases are 158, Controls are 158 and total population are 316 persons. In the table, + mean “and above”, “<” means less than & “>” means more than. Parenthesis (-) shows range of values while % means percentage.

Variable	Unadjusted model		Adjusted model	
	OR (95% CI)	P-value	AOR (95% CI)	P-value
Road traffic injury (RTI)	2.09(1.33-3.30)	0.002**	2.83(1.62-4.93)	0.001***
Blunt trauma	1.22(1.03-1.44)	0.019*	1.21(1.00-1.46)	0.053
Weekday trauma	0.97(0.59-1.58)	0.900	0.69(0.38-1.24)	0.212
Age categories (ref: 40+ years)		0.725		0.798
18-29 years	0.82(0.48-1.41)	0.476	0.92(0.48-1.78)	0.808
30-39 years	0.97(0.54-1.74)	0.920	1.14(0.56-2.30)	0.715
Female gender	1.64(0.88-3.08)	0.119	2.76(1.29-5.92)	0.009**
Trauma severity (ref: Severe GCS<9)		0.001***		0.001***
Severe (GCS<9)	4.28(2.48-7.39)	0.001***	3.42(1.84-6.36)	0.001***
Moderate (GCS 9-12)	1.81(0.94-3.48)	0.075	1.54(0.73-3.24)	0.258
Presence of hypoxemia	4.36(2.58-7.36)	0.001***	4.75(2.60-8.68)	0.001***
Presence of comorbidity	1.27(0.81-2.00)	0.299	1.82(1.03-3.22)	0.040*
Alcohol use	1.72(1.05-2.85)	0.033*	2.57(1.40-4.73)	0.002**
Pre-hospital time (ref: 6+ hours)		0.026*		0.639
<3 hours	0.49(0.29-0.82)	0.007**	0.39(0.02-8.39)	0.545
3-6 hours	0.67(0.33-1.36)	0.274	0.71(0.30-1.67)	0.432
Public tertiary facility (KNH)	2.34(1.49-3.68)	0.001***	2.18(1.21-3.94)	0.009**
Access to pre-hospital care	0.58(0.37-0.91)	0.018*	0.58(0.03-12.37)	0.728

\*p<0.05.

\*\*p<0.01.

\*\*\*p<0.001.

AOR, adjusted odds ratio; CI, confidence interval; GCS, Glasgow Coma Scale; KNH, Kenyatta National Hospital; OR, odds ratio.

high burden of post-trauma mortality and morbidity.<sup>28,33,34,36</sup> More than 50% of trauma is RTI-related.<sup>22</sup> In Africa and other LMICs such as Ghana, India, Kenya and Uganda, the negative impact of an increase in motorcycle injuries is an increasing public health problem reflected by huge cases of RTI-related fatalities and morbidities.<sup>22,28,33,34</sup> Kenya has seen an unprecedented increase in motorcycle motorization, which has exponentially increased trauma burden such as mortality and disability.<sup>33</sup> In some LMICs, injury burden from motorcycles has exceeded those from other motorized vehicles.<sup>28,33</sup> This has been worsened by lack of EMS care capacity at the pre-hospital care level to respond to increasing demand for quality care in settings outside of hospital.<sup>45</sup>

Pedestrians, unrestrained passengers and motorists are the most commonly injured patients due to high exposure risks when crossing roads and walking along major roads. In addition to non-adherence to road traffic rules among motorists, poor road infrastructure contributes to increased risk of RTIs.<sup>16,22</sup> For instance, many major roads have limited provisions for safe walkways and cycling paths, further exposing road users to avoidable injuries. Road safety and awareness campaigns have not been adequately successful in injury and mortality risk reduction.<sup>46,47</sup> Complementing these efforts with effective on-scene EMS responses can provide possible survival and health outcome benefits. This requires continued mapping and review of trauma pattern profiles as well as their effect on mortality in both rural and urban areas to inform trauma-specific responses. Consistent with other studies,<sup>28</sup> the head was found to be the most injured body part. This is expected because our study population are TBI patients. Chalya *et al.*<sup>28</sup> reported head injuries are the leading cause of deaths and disability in TBIs. Head injuries are associated with an increase in odds of death of around 1.5 times<sup>48</sup> compared to non-head injuries. Similar to this study, lower extremities were also found to be frequently injured. The limbs sustain wounds, abrasions laceration, amputations or fractures which constitute significant morbidity risks such as disability as well as deaths due to uncontrolled hemorrhage. Serious head injuries present with life-threatening outcomes such as intracranial hemorrhage, which require timely life-saving interventions. Brain contusion and concussions were frequent

form of injuries attributed to blunt injuries. These brain injuries can pose significant mortality risks if not managed effectively and promptly in line with the "Golden Hour" concept.<sup>33,45</sup> This concept argues that life-saving interventions are to be provided within one hour after injury for high efficacy while preventing irreversible pharmacological changes associated with higher mortality risks. Internal head and brain injuries are easily missed (missed injuries) due to poor diagnosing capability and lack of trained staff at the pre-hospital care level. Gaps in pre-hospital life-saving responses significantly increase the risk of preventable mortality.<sup>33,45</sup> Quality pre-hospital trauma responses matching skill and resource needs are lacking in these settings, hence a higher case load of avoidable fatalities and disabilities. This burden can be averted using effective and timely out of hospital settings EMS responses targeting this type of trauma.

Blunt trauma is frequently reported in RTIs<sup>37,38</sup> while penetrating trauma is frequent in gunshots, stabs and other invasive trauma. Type of injury (blunt or penetrating) was not a predictor of TBI mortality after adjusting for other variables and confounders. This is inconsistent with other studies which showed penetrating trauma to increase mortality significantly.<sup>36,37</sup> However, unlike our study, in these studies, which included other types of trauma such as central nervous system (CNS) injuries and amputations, penetrating trauma was most frequently reported. This variation in trauma mechanism and pattern may partially explain the difference in results. Blunt trauma was associated with increased odds of mortality, although this association was not significant. This is attributed to the role of RTI which is the main source of blunt injuries.

We further investigated the effect of injury day on TBI mortality. We found distribution of injuries to be similar across weekdays. There was also no significant difference in TBI outcomes when weekend and weekday injuries distribution were compared. While the study doesn't provide sufficient evidence to refute the existing argument that TI (morbidity) is a predominantly a weekend problem due to high number of social events and mobility,<sup>19,28,39</sup> it suggests that TBI morbidity may not be predominantly a weekend problem as expected. We found no published study examining the influence of injury day on TBI mortality. One study by Möller *et al.* examined a different but related aspect, the influence of hospital admission day on all forms of trauma mortality.<sup>36</sup> The study showed high trauma case admissions during weekends, especially between midnight and six o'clock in the morning compared to weekdays.<sup>36</sup> In the study, hospital admission day was significantly associated with mortality in which more deaths were noticeable on Tuesdays and Fridays. However, due to the small sample size in which the observed cell frequencies for these days was less than five, generalization of the evidence was low.

Further, a descriptive study from Tanzania found higher rates of injuries during the day but did not examine the influence of day of injury dynamics on mortality.<sup>28</sup> We note that during the day, injury exposure is high due to higher mobility due to travel to workplaces, engagement in economic activities and other social events. Our study did not examine the difference between day and night injuries due to a lack of data on this injury characteristic. A lack of robust and comprehensive trauma registries across LMIC countries that capture injury day and other injury data is the main reason for this study gap. As a result, most authors use trauma admission time, which is easily found in patient records, as proxy indicator of injury day. In LMICs, pre-hospital delays can be as high as seven days due to missed injuries and under-triaging and hence are a possible reason for the difference in mortality between injury day and admission day after trauma.

We also included type of transfer facility in the adjusted predictor model. To our knowledge, this is the first published study to control for type of tertiary facility as an important contextual and control factor that can significantly alter mortality distribution. We found type of tertiary transfer facility to be significantly associated with TBI mortality, both independently and after adjustment of other variables. In this study, risk of dying was significantly higher among patients transferred to a public tertiary facility compared to a private facility. Access to pre-hospital care (from trained EMS providers) and differences in care among public and private transfer facilities can alter mortality due to differences in quality of life-saving and trauma care interventions provided as part of care continuity. Patient transfer to well-equipped facilities can have substantive benefits for survival outcomes by leveraging on effective EMS at the prehospital care level. In LMICs, private facilities are known to be better equipped and staffed than public facilities, hence creating variations in care quality. For instance, at minimum, a well-equipped trauma care facility should provide computerized tomography (CT) scanning, hemorrhage control, provision of IVs, neurosurgical care, Intensive Care Unit, intracranial monitoring and treatment among others as part of critical care.<sup>49</sup> Availability of these facilities, resources and equipment may vary substantively across public and private facilities.

In Kenya and other LMICs, most public referral facilities have limited resources to attend to a high number of patients linked to poor leadership and underfunding, hence possible suboptimal care.<sup>9,17</sup> There are also care delays due to over-triaging and ineffective governance systems to support timely and optimal trauma care compared to public facilities.<sup>14,26</sup> In public facilities, there are limited theatres and experts to serve a high number of casualties especially in cases of mass casualty.<sup>49</sup> Qualified trauma specialists are also frequently away in public practice, leading to delays in life-saving care. In private tertiary facilities, trauma care is promptly provided due to manageable numbers of TBI patients seeking care.<sup>50</sup> The facilities are also well equipped and resourced to provide specialized care with readily available specialists. This allows maximal care, leading

to improved outcomes compared to public facilities. However, high medical fees in private facilities, combined with lack of comprehensive health insurance among the poor and most vulnerable result in limited access to private facility trauma care services.<sup>19,20</sup> Addressing gaps in capacity of public facilities has been identified as an important intervention to reduce avoidable pre-hospital mortality and morbidity burden most prevalent among the less well-off.<sup>6,10,51</sup>

## Conclusion

Trauma mechanism was the only trauma pattern significantly associated with TBI mortality. Blunt trauma, especially from RTI, is a key driver of increasing TBI mortality burden at the prehospital care level. Strengthening local trauma emergency care responses targeting RTIs - including but not limited to equipping lower public facilities with adequate resources including well-equipped and organized ambulances, trained critical care providers, essential medical supplies and equipment - can offer potential life-saving benefits to RTI casualties.

## Data availability

### Underlying data

Harvard Dataverse: Association between Traumatic Brain Injury (TBI) patterns and mortality. <https://doi.org/10.7910/DVN/TF4LXE><sup>52</sup>

This project contains the following underlying data:

- Data Gilbert\_SPSS Data-Jo- 1.tab

This project also contains the following extended data:

- Medical Records Review Checklist.docx

### Extended data

Harvard Dataverse: Replication Data for: Association between Traumatic Brain Injury (TBI) patterns and mortality. <https://doi.org/10.7910/DVN/TK8BXF>

This project contains the following extended data:

- Data Gilbert\_SPSS Data-Jo- Hav.tab

Data are available under the terms of the [Creative Commons Zero “No rights reserved” data waiver](#) (CC0 1.0 Public domain dedication).

## Acknowledgments

The authors thanks Mr. Martin Mwenda, Ms. Winfred Kananu, Ms. Faith Ngatia and Mr. Bonface Muthomi for their assistance in data collection and reviews. We thank all health facilities and institutions which supported and participated in the study, either directly or indirectly. Special thanks to the management of KNH, Kikuyu Mission Hospital and Mater Misericordiae Hospital for institutional approval and administrative support in abstraction of patient records data in their facilities. We are greatly thankful to all persons who participated either directly or indirectly in this study.

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Current Peer Review Status:  

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## Version 2

Reviewer Report 09 February 2022

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**Amit Agrawal** 

Department of Neurosurgery, All India Institute of Medical Sciences, Bhopal, Bhopal, Madhya Pradesh, India

The authors have made appropriate changes.

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Neurosurgery

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

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## Version 1

Reviewer Report 19 January 2022

<https://doi.org/10.5256/f1000research.58163.r93345>

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**Peter Kithuka**

Department of Health management and Health Informatics, Kenyatta University, Nairobi, Kenya

This article provides answers to the hitherto unclear research gaps with respect to the association between traumatic brain injury patterns and mortality. This paper addresses important public health issues which have attracted limited attention in Africa over time. The authors' methodology

is scientifically sound in which the findings are well anchored. The conclusions of this study will go a long way in informing important policy deliberation and further research into this area. Except for a few issues raised that need to be rephrased for clarity, the study has a robust and sound scientific base on this topic. Specifically, check on:

- **Background:** The content is very relevant and logically present. However, some literature, well captured in the discussion can be cut down.
- **Statistical Analysis:** Revise the second sentence in this section to read: "we used Pearson's chi-square test to determine the association between trauma pattern and mortality outcomes".

The author can also provide more details on the control group used in this study.

- **Results:** Rephrase the first sentence in this section to read: "A descriptive summary of study population characteristics versus mortality outcomes is shown in [Table 1](#)."
- **Discussion:** No comments – the discussion section is well anchored on the findings presented.
- **Conclusion:** The conclusion is fairly supported by study results or data. However, the author can consider paraphrasing the first sentence to read: "This study aimed to assess the association between trauma patterns and TBI mortality."

The conclusion should also be reviewed to focus on trauma patterns (RTI and other patterns studied) rather than the type of facility a patient is transferred to; the type of tertiary facility is presented and incorporated as a control variable in line with the statistical analysis used.

**Is the work clearly and accurately presented and does it cite the current literature?**

Yes

**Is the study design appropriate and is the work technically sound?**

Yes

**Are sufficient details of methods and analysis provided to allow replication by others?**

Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**

Yes

**Are all the source data underlying the results available to ensure full reproducibility?**

Yes

**Are the conclusions drawn adequately supported by the results?**

Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Health Systems Management

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.**

Author Response 27 Jan 2022

**Gilbert Gilbert**, University of Nairobi, Nairobi, Kenya

The content is very relevant and logically present. However, some literature, well captured in the discussion can be cut down.

*We deleted literature on page 4 which presented findings on the relationship between trauma patterns and mortality outcomes and trauma statistics from high-income countries. Most of this literature was already incorporated into the discussion. This was done to make the introduction section short and concise.*

The author can also provide more details on the control group used in this study.

*Additional details on the control group were added.*

Revise the second sentence in this section to read: "we used Pearson's chi-square test to determine the association between trauma pattern and mortality outcomes"

*Revision is done to read as follows, "We used Pearson's chi-square test to determine the association between trauma pattern".*

Rephrase the first sentence in this section to read: "A descriptive summary of study population characteristics versus mortality outcomes is shown in **Table 1**."

*The sentence was reviewed to read, "A descriptive summary of study population characteristics and mortality distribution is shown in Table 1".*

The conclusion should also be reviewed to focus on trauma patterns (RTI and other patterns studied) rather than the type of facility a patient is transferred to; the type of tertiary facility is presented and incorporated as a control variable in line with the statistical analysis used.

*In the conclusion, deduction on the effect of type of tertiary facility transfer on mortality outcomes was removed to retain the emphasis on the association between trauma patterns and TBI mortality.*

**Competing Interests:** No competing interest

Reviewer Report 25 October 2021

<https://doi.org/10.5256/f1000research.58163.r94017>



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**Amit Agrawal** 

Department of Neurosurgery, All India Institute of Medical Sciences, Bhopal, Bhopal, Madhya Pradesh, India

The topic of the current article is pertinent and is of public health importance.

- The introduction is too long and can be shortened to include relevant details.
- It will be interesting to provide the total number of cases of TBI presented to the hospital and how the unmatched sample was drawn (equal number of cases versus controls).
- It will be helpful if the details of the control group can be elaborated (healthy versus others).
- Please provide further details of how ICD codes were assigned or selected as it will help in future studies.
- Please provide further details and numbers of excluded cases.
- It will be interesting to have the details of isolated TBI versus TBI and associated injuries and their outcomes.
- Please elaborate in Table 1 GCS if it is for TBI severity not for Trauma Severity; accordingly the text can be updated.
- In reference to the title of Table 1: "Patient characteristics summary by mortality outcome (cases and controls)" - is it mortality outcome or is it a table of characteristics of the study population with subgroup distribution? Similarly, Table 2, "Descriptive summary of trauma patterns by mortality outcomes".
- In other tables when the objective of the study is to include patients with TBI, the distribution of injuries cannot be generalized, rather it will be a distribution of associated injuries in patients with TBI. Accordingly, the language needs to be modified and sentences may need to be re-phrased.
- Once these are potentially incorporated it will be great if the discussion can be modified and updated as well.
- Please support the conclusion by the study findings and it should reflect the objectives of the study.
- Few references are incomplete and need to be updated.
- It is obvious that retrospective design shall have inherent limitations, the statistical methods have text that can better be shifted to the methods section particularly "Access to life-

saving...".

- Although the study does not provide new information, however, it can be a good contribution to understanding regional (i.e. Kenya in the present case) patterns and burden of traumatic brain injury-related morbidity and mortality.

**Is the work clearly and accurately presented and does it cite the current literature?**

Partly

**Is the study design appropriate and is the work technically sound?**

Partly

**Are sufficient details of methods and analysis provided to allow replication by others?**

Partly

**If applicable, is the statistical analysis and its interpretation appropriate?**

Partly

**Are all the source data underlying the results available to ensure full reproducibility?**

Partly

**Are the conclusions drawn adequately supported by the results?**

Partly

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Neurosurgery

**I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.**

Author Response 27 Jan 2022

**Gilbert Gilbert**, University of Nairobi, Nairobi, Kenya

The introduction is too long and can be shortened to include relevant details

*We deleted literature on page 4 which presented findings on the relationship between trauma patterns and mortality outcomes and trauma statistics from high-income countries. Most of this literature was already incorporated into the discussion. This was done to make the introduction section short and concise.*

It will be interesting to provide the total number of cases of TBI presented to the hospital and how the unmatched sample was drawn (equal number of cases versus controls).

*We included the number of TBI cases and controls presented to the facilities in the study period to*

*provide more details on the sampling frame.*

Please provide further details of how ICD codes were assigned or selected as it will help in future studies

*This was added. The codes are assigned based on the written medical notes (documentation) on patient examination and diagnosis by the clinical care providers.*

It will be interesting to have the details of isolated TBI versus TBI and associated injuries and their outcomes.

*This analytic request was not at the center of this study – is outside our scope – but details of the sampled injuries are listed in Table 3.*

It will be helpful if the details of the control group can be elaborated (healthy versus others)

*Additional details on the control group were added.*

Please provide further details and numbers of excluded cases.

*Details and the number of excluded cases have been provided.*

In reference to the title of Table 1: "Patient characteristics summary by mortality outcome (cases and controls)" - is it mortality outcome or is it a table of characteristics of the study population with subgroup distribution? Similarly, Table 2, "Descriptive summary of trauma patterns by mortality outcomes".

In other tables when the objective of the study is to include patients with TBI, the distribution of injuries cannot be generalized, rather it will be a distribution of associated injuries in patients with TBI. Accordingly, the language needs to be modified and sentences may need to be re-phrased.

*The title of Table 1 was revised to indicate the data presented was on study population characteristics versus mortality distribution rather than patient characteristics and mortality outcomes.*

Please elaborate in Table 1 GCS if it is for TBI severity not for Trauma Severity; accordingly the text can be updated.

*The use of GCS scores to refer to trauma severity was replaced with TBI severity in the entire document.*

Once these are potentially incorporated it will be great if the discussion can be modified and updated as well.

*The discussion was updated with suggested details including change of trauma severity to TBI*

*severity and use of mortality distribution instead of mortality outcomes.*

Please support the conclusion by the study findings and it should reflect the objectives of the study.

*In the conclusion, deduction on trauma patterns in which deductions on the effect of type of tertiary facility transfer on mortality outcomes was removed to retain an emphasis on association between trauma patterns and TBI mortality.*

**Competing Interests:** No competing interest

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