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Survival status and predictors of mortality among traumatic brain injury patients in an Ethiopian hospital: A retrospective cohort study

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ABSTRACT

Introduction: Traumatic brain injury is a major global public health problem causing substantial mortality among the adult population. Hence, this study aimed to determine the predictors of mortality among adult traumatic brain injury patients in Felegehiwot Comprehensive Specialized Hospital in Northwest Ethiopia during 2020.
Methods: A retrospective cohort study was conducted at Felegehiwot Comprehensive Specialized Hospital using anonymized patient data obtained from chart review. Descriptive statistics were used to summarise the patient characteristics. The Kaplan–Meier survival curve and log-rank test were used to test for differences in survival status among groups. The Cox proportional hazards regression model was used at the 5% level of significance to determine the net effect of each explanatory variable on time to death.
Results: In total, 338 patients aged ≥15 years and diagnosed with traumatic brain injury were included in the analysis. Among these patients, 103 (30.45%) died, giving a crude death rate of 25.53 per 1000 (95% CI: 21.05–30.98) person-days of follow-up. The overall median survival time was 44 days. The independent predictors of mortality after diagnosis of traumatic brain injury were admission Glasgow coma scale score ≤ 8 (adjusted hazard ratio (AHR): 4.85; 95% confidence interval (CI): 1.73–13.62), bilateral non-reactive pupils at admission (AHR: 2.00 (95% CI: 1.10–3.71), elevated systolic blood pressure at admission (AHR: 0.31; 95% CI:0.11–0.86), elevated diastolic blood pressure at admission (AHR: 3.54; 95% CI: 1.33–9.43), and haematoma evacuation (AHR: 0.42; 95% CI: 0.16–0.90).
Discussion: The Survival status of traumatic brain injury patients was relatively low in this study. Glasgow coma scale score, bilateral non-reactive pupils, and elevated blood pressure were significant predictors of mortality. Further prospective follow-up studies that include residence and occupation are recommended.

African relevance

- This study is relevant to the advancement of the field of interest, as there is scarcity of studies in Africa, as well as in Ethiopia.
- The government of Ethiopia aimed to reduce accident-related mortality (mainly car accidents), but it was not successful, so this study will provide additional data for policymakers to take action.
- Since there are no similar studies in Ethiopia, it will also be used as a baseline data for other researchers.
- This study helps to increase such patients' quality of life and reduce burden of hospitals due to TBI related mortality and it will also decrease health care cost due to TBI in Africa as well in Ethiopia.

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Introduction

Traumatic brain injury (TBI) is a non-degenerative, non-congenital insult to the brain due to an external mechanical force, which possibly leads to permanent or temporary impairment of cognitive, physical, and psycho-social functions, with an associated altered state of consciousness or death [1,2]. Mortality due to TBI is determined by two substantially different mechanisms/stages: the primary insult that occurs at the moment of impact and the secondary insult (consecutive pathological processes) initiated at the moment of injury with delayed clinical presentations [3].

TBI is often referred to as the "silent epidemic", and this growing public health concern represents the greatest contributor to death throughout the world among all trauma-related injuries [4,5]. Globally, over 69 million people are estimated to suffer TBI from all causes each year, with more than 4.7 million deaths annually [6]. Based on the gross national income per capita value, the World Bank classifies countries as having low, middle, or high incomes [7]. Studies have shown that the incidence and mortality related to TBI are higher in low- and middle-income countries (LMICs) than high income countries [8–11]. Data from LMICs suggest that up to half of all trauma-related mortality is attributed to injury to the brain [12,13].

The risk of mortality in patients with TBI in LMICs, including sub-Saharan Africa, is more than two to three times as high as that for patients in high income countries [14,15]. The sub-Saharan Africa region has a TBI-related mortality incidence of 150 to 170 per 100,000 compared with a global average of 106 per 100,000 [18]. This higher magnitude in LMICS might be due to several reasons. In particular, TBI patients need to overcome transport and cost barriers before they can receive treatment in a health institution and specially to reach referral hospitals [16]. Patients receive little prehospital medical care before or during transport due to the unavailability of well-established rescue systems [17]. The incidence of TBI-related mortality is probably an underestimate due to the lack of trauma care infrastructure and a well-established trauma reporting system, and thus many patients present late at hospital and their mortality may be underreported. Moreover, TBI-related deaths are underreported because victims are probably first routed to mortuaries, as 50% of TBI-related mortality occurs within the first 2 h from the moment of primary injury [18].

The burden of TBI-related mortality is evident in all regions throughout the world, but it is especially prominent in LMICs, including Ethiopia. However, related studies are generally conducted in developed regions of the world where the case rate is lower compared with LMCIs such as Ethiopia. TBI-related mortality caused mainly by road traffic accidents and assault is a public health problem that mostly affects young adults and males in Ethiopia [19–22]. According to a study conducted at Jimma Referral Hospital, TBI-related mortality is 21.2% in Ethiopia [19]. Few studies have investigated the predictors of in-hospital mortality secondary to TBI and the survival status among adult patients in Ethiopia. Hence, in this study, survival status and predictors of TBI-related mortality were retrospectively determined among adult patients hospitalized during 2020 in Felegehiwot Comprehensive Specialized Hospital (FHCSH), Amhara region, Northwest Ethiopia.

The aim of this study was to assess survival status and predictors of mortality among traumatic brain injury patients in Felegehiwot comprehensive specialized hospital, Amhara regional state, northwest Ethiopia, 2015–2019.

Specific Objectives were to determine survival status of traumatic brain injury patients in Felegehiwot comprehensive specialized hospital, Amhara, Ethiopia, 2020 and to identify predictors of hospital mortality among traumatic brain injury patients in Felegehiwot comprehensive specialized hospital, Amhara, Ethiopia, 2020.

Methods

An institution-based retrospective follow-up study was conducted among a cohort of patients aged ≥15 years from January 1, 2015 to December 31, 2019. The study was conducted at FHCSH in Bahir Dar, which is the capital city of the Amhara region in Ethiopia. Bahir Dar City is located approximately 565 km northwest of Addis Ababa. The hospital has more than 400 beds and it serves over 5,000,000 people. The hospital has 27 specialist physicians, 83 general practitioners, 383 nurses, three BSc holder psychiatry nurses, and 13 public health officers. The study was conducted from February 25, 2020 to March 28, 2020. In total, data were obtained for 2377 TBI patients between January 1, 2015 and December 31, 2019 from health information and management system (HIMS) at FHCSH Emergency outpatient department (EOPD). After obtaining the list, the medical record numbers of the patients were entered into Microsoft Excel 2010 software and the sampling frame was prepared based on random numbers. Study participants were selected using a computer-generated simple random sampling method from the sampling frame to obtain a sample of medical records for 372 patients. Our source population comprised patients aged ≥15 years who were admitted to FHCSH with a diagnosis of TBI between 2015 and 2019. The study unit comprised all patients selected by the computer-generated simple random sampling technique.

All patients recruited were aged ≥15 years, diagnosed with TBI, and admitted to FHCSH during 2015–2019, and incomplete patient charts were excluded.

The total sample size was determined with the double population proportion formula using G-power version 3.1 software by assuming a one-to-one ratio of exposed to non-exposed, 95% level of confidence, and power of 80%. The total sample size was determined based on a comparable study conducted in Tanzania of factors that predicted the outcome of post-TBI mortality. Four significantly associated factors comprising systolic blood pressure on admission, Glasgow coma scale (GCS) score, computed tomography pathology, and age with TBI-related mortality were used to determine the sample size, and age as a post-TBI mortality predictor yielded the largest sample size (338 patients) with 169 patients medical records for each group [23]. After considering that incomplete patient charts and medical records were lost during data collection, a contingency of 10% was allowed for each group and 34 TBI patient charts were added to the initial sample. Thus, the final sample size was 372 TBI patients.

Dependent variable

Time from diagnosis to death of TBI patients.

Independent variables

Socio - demographic characteristics were age and sex. Institutional and injury-related factors were source of referral, duration until presentation at FHCSH, interventions at referring institution, interventions at FHCSH, mode of arrival, mechanism of injury, type of injury, the coexistence of extracranial injuries. Clinical and radiological characteristics were TBI severity based on GCS, pupillary reactivity, platelet count, computed tomography and radiological findings (subdural, Intracerebral, subarachnoid and ventricular haemorrhage, and skull fracture), time elapsed since injury, vital signs during admission to FHCSH, and vital signs 48 h after admission to FHCSH.

An English version checklist was used to collect the necessary data from the charts of the study participants. The checklist was adapted from previous comparable studies and it contained the following five sections: socio - demographic characteristics, mechanism of injury, institution-related factors, clinical characteristics, and radiological findings [24–26]. Data were collected by four nurses with bachelor's degrees who were supervised by two emergency and critical nursing, and comprehensive nursing specialists with MSc degrees. Three days before the

actual data collection period, one day of training was provided to the supervisors and data collectors.

The quality of the data was assured by adapting a valid data extraction tool. The checklist was evaluated by experienced researchers and pretested based on 5% of the sample. Training was provided to the data collectors and supervisors regarding the data extraction checklist and data collection process. During the data collection period, close supervision and monitoring were conducted by the supervisors and investigators. Double data entry was also conducted using Epi Data version 4.6.0.2 software.

The collected data were verified, coded, and entered into Epi Data version 4.6.0.2 software and then exported to SPSS version 26 software for cleaning. After cleaning, analyses were conducted using Stata version 14.2software. The Kaplan–Meier survival curve was calculated to estimate the median survival times. A log-rank test was used to compare survival curves between categorical variables. The necessary assumptions in the Cox proportional hazards model were checked using the scaled Schoenfeld residuals test, graphical log (−log (survival)) plot, and time-dependent variables test. Variance inflation factor and pairwise comparison tests were performed to detect the presence of multicollinearity between each independent variable, and the Cox proportional hazards regression model was then used to test the association between each independent variable and the dependent variable. Bivariate Cox regression analysis was used to assess the relationship between each predictor variable and TBI-related mortality. Variables with $p < 0.25$ and TBI-related mortality in the bivariate Cox proportional hazards regression model were entered into the multivariate Cox proportional hazards regression analysis model. Statistically significant associations between predictors and post-TBI-related mortality were accepted at $p < 0.05$ as the cutoff point (expressed as the mean and 95% confidence interval). The normal distributions of the data were checked and the Shapiro –Wilk test was then conducted. Results were expressed as percentages, means, medians, interquartile ranges, standard deviations, rates, and hazard ratios. Finally, the results were presented as text, tables, and graphs.

Ethical clearance was obtained from the ethical review committee of Bahir Dar University College of Medicine and Health Sciences with ethical approval letter number 0023/2020. Subsequently, permission was obtained from the hospital's quality assurance office, relevant departments, and unit heads of the hospital. The study was conducted using appropriate information from the patient's medical record, so it did not inflict any harm on the patients. Names and other identifying information were not recorded in the checklist and all information used from the charts was kept confidential in a secret place and on password-protected personal computers.

Operational definitions

Censored

TBI patients who did not develop the outcome of interest (death) at the end of the follow-up period, lost to follow-up, transferred to a different institution, or who died before admission to FHCSH.

Event

Occurrence of death from the first confirmed diagnosis of TBI until the end of the study at FHCSH.

Time to death

Calculated as the number of days between the date of unequivocal diagnosis of TBI until the date of death.

Results

Socio demographic characteristics and medical condition of study participants

Over the five-year study period, 2377 TBI cases were admitted to FHCSH. The computer-generated random sampling technique selected 372 patient charts and 338 patient charts were eligible for this study. The median age of participants at the time of admission was 30 years (95% confidence interval (CI): 28–30.53). The highest number of participants died in the 26–36 years age group (36.3%). The socio - demographic and medical characteristics of the study participants are shown in Table 1.

Mode of arrival and characteristics of study participants

Most of the study participants (211, 62.4%) were referred from other institutions and the median duration until presentation at the FHCSH was 6 h (95% CI: 5–6 h). Road traffic accidents (127, 37.6%) and assault/violence (125, 36.7%) were the main causes of admission. The median GCS score at admission was 8–9 at 95% CI. Based on the GCS score at admission, half (169, 50%) of the TBI patients were diagnosed with severe TBI. The median systolic and diastolic blood pressures at admission were 110 mmHg (95% CI: 105–110) and 70 mmHg (95% CI:), respectively (Table 2).

Survival status of TBI patients

The overall mortality rate in the cohort during the 4032.99 person-days of observations was 25.53 per 1000 (95% CI: 21.05–30.98) person-days of follow-up. The cumulative incidence in this study was 103 (30.45%) during the study period of 80 days. However, 235 (69.5%) were censored until the end of the study. Among these patients, 127 (37.6%) were discharged with full recovery, 67 (19.8%) were discharged with disability, 36 (10.7%) left against medical advice, two (0.6%) were transferred to other institutions, and three (0.88%) were lost at the end of the follow-up. Thus, patients diagnosed with severe TBI (GCS $\leq$ 8) had a 2.47 times higher risk of death compared with patients with moderate TBI (GCS: 9–12) (Crude HR: 2.47; 95% CI: 1.37–4.428) and a 7.19 times higher risk of death compared with patients with mild TBI (Crude HR: 7.19; 95% CI: 3.13–16.51).

Table 1
Socio demographic characteristics and medical conditions of traumatic brain injury patients at Felegehiwot Comprehensive Specialized Hospital, Bahir Dar, Ethiopia, from January 1, 2015 to December 31, 2019 ($N = 338$).

Covariate	Category	Vital status at last date of contact		Total no. (%)
		Censored no. (%)	Death no. (%)	
Sex	Male	179 (70.8)	74 (29.2)	253 (74.9)
	Female	56 (65.9)	29 (34.1)	85 (25.1)
Age	15–25	83 (24.6)	28 (25.2)	111 (32.8)
	26–36	65 (63.7)	37 (36.3)	102 (30.2)
	37–47	33 (70.2)	14 (29.8)	47 (13.9)
	48–58	25 (77.4)	10 (28.6)	35 (10.4)
	59–75	29 (67.4)	14 (32.6)	43 (12.7)
Pre-existing medical conditions	Yes	17 (85%)	3.0 (15.0%)	20 (5.9%)
	No	218 (68.6)	100 (31.4)	318 (94.1%)
Co-existing aspiration pneumonia	Yes	72 (49.3%)	74 (50.7%)	146 (43.2%)
	No	163 (84.9%)	29 (15.1%)	192 (56.8%)

Table 2
Mode of arrival and characteristics of study participants at Felegehiwot Comprehensive Specialized Hospital, Bahir Dar, Ethiopia, from January 1, 2015 to December 31, 2019 ($N = 338$).

Vital status at last date of contact				
Variables	Category	Censored no. (%)	Death no. (%)	Total no. (%)
Admission	Directly admitted to FHCSH	90 (70.9)	37 (29.1)	127 (37.6)
	Referred from other institution	145 (62.4)	66 (37.6)	211 (62.4)
Mode of arrival	On foot	24 (85.7)	4 (14.3)	28 (8.3)
	By ambulance	48 (63.2)	28 (36.8)	76 (22.5)
	By private car/ public service	146 (74.5)	50 (25.5)	196 (56)
	By stretcher	17 (44.7)	21 (55.3)	38 (11.2)
Mechanism of injury	Road traffic accident	73 (57.5)	54 (42.5)	127 (33.4)
	Assault/violence	94 (75.2)	31 (24.8)	125 (37.0)
	Fall	68 (75.8)	18 (24.2)	86 (26.9)
Type of head injury	Blunt head injury	94 (79.1)	26 (21.7)	120 (35.5)
	Penetrating head injury	141 (64.7)	77 (33.3)	218 (64.5)
The severity of TBI based on Admission GCS	Mild TBI (GCS ≥13)	99 (94.3)	6 (5.7)	105 (31.1)
	Moderate TBI (GCS = 9–12)	51 (79.7)	13 (20.3)	64 (18.9)
	Severe TBI (GCS ≤8)	85 (50.3)	84 (49.7)	169 (50.0)
Pupillary reactivity during admission	Bilateral reactive	163 (85.8)	27 (14.2)	190 (56.2)
	Unilateral reactive	29 (59.2)	20 (40.8)	49 (14.5)
	Bilateral non-reactive	43 (43.4)	56 (56.6)	99 (29.3)
Hypoxia based on admission SpO_2	$SpO_2 < 90$ mmHg	178 (71.5)	71 (28.5)	249 (73.7)
	$SPO_2 \geq 90$ mmHg	57 (64.0)	32 (36.0)	89 (26.3)
Systolic blood pressure at admission	< 90 mmHg	42 (62.7)	25 (37.3)	67 (19.8)
	90–139 mmHg	173 (51.2)	48 (48.8)	221 (65.4)
	≥140 mmHg	20 (40.0)	30 (60.0)	50 (14.8)
Elevation	Yes	48 (71.6)	19 (28.4)	67 (19.8)
	No	186 (55.2)	85 (44.8)	273 (80.2)
Burr hole	Yes	39 (67.2)	19 (32.8)	58 (17.2)
	No	195 (69.6)	85 (30.4)	280 (82.8)
Haematoma evacuation	Yes	100 (73.0)	37 (27)	137 (40.5)
	No	134 (66.7)	67 (33.3)	201 (59.5)
Craniotomy	Yes	84 (77.1%)	25 (22.9%)	109 (22.4)
	No	150 (65.5)	79 (34.5%)	229 (67.6)

FHCSH, Felegehiwot Comprehensive Specialized Hospital; GCS, Glasgow coma scale; TBI, traumatic brain injury.

Overall survival of TBI patients

In this study, 338 TBI patients were followed up for a total of 4033 days and the median survival time was 44 days. Survival estimation based on the Kaplan–Meier curve showed that the overall estimated survival rate after diagnosis of TBI was 47.53% (95% CI: 37.27–57.08) after 4032.99 days of follow-up. The estimated cumulative survival was 94.01% (95% CI: 90.87–96.10) within the first 24 h of follow-up, 89.63% (95% CI: 85.78–92.48) after 48 h of follow-up, 86.03% (95% CI:81.73–89.38) after 72 h of follow-up,75.13% (95% CI: 69.16–79.44%) after 1 week of follow-up, 53.94% (95% CI: 45.48–61.66) after 30 days of follow-up, and 47.53 (95% CI: 37.27–57.08) after 80 days of follow-up.

The probability of survival decreased as the follow-up time increased, especially within the first days of follow-up according to the Kaplan–Meier survival curve for time to death for TBI patients. The highest rate of mortality occurred between the first day and 34th day after TBI diagnosis (Fig. 1).

Survival status among different groups of TBI patients

A log-rank test was performed to test the equality of the survival curves in order to detect significant differences in the survival time according to the various levels of the categorical variables considered in this study. The test statistics showed that the survival time varied significantly according to the different categorical variables. The Kaplan–Meier curve provided significant evidence of differences in the survival times. The median survival time for those who arrived by ambulance and public/private service was longer than that for those who arrived at the FHCSH hospital by stretcher (8 days (95% CI: 4–21), and the difference was statistically significant at $p < 0.001$. The median survival time for TBI patients admitted due to blunt head injury was 44 days, which was longer compared with the median survival time for those admitted due to penetrating head injury (23 days), and this difference was statistically significant at $p = 0.037$.

Among 169 (50.0%) TBI patients diagnosed with severe TBI (GCS ≤ 8) based on their GCS score at admission, the cumulative survival was 36.92% (95% CI; 27.09–46.77%), whereas that for the patients diagnosed with moderate TBI 46.60% (95% CI: 10.26–77.41%) and those for the remaining mild TBI patients 75.03% (95% CI: 35.26–92.39%). Thus, TBI-related mortality was correlated with the severity of TBI at diagnosis and the testing equality among groups, with $p < 0.001$. Among 99 (29.29%) TBI patients who had bilateral non-reactive pupils at admission, the cumulative survival was 29.13% (95% CI: 17.96–41.22%) which was lower compared with the cumulative survival of patients who had unilateral reactive pupils (35.95%; 95% CI: 13.63–59.15%) and bilateral reactive pupils (55.19%; 95% CI: 20.41–80.06%) (Table 3 and Figs. 2 and 3).

The Kaplan–Meier survival curve showed that the mean survival time for those diagnosed with TBI and additional extracranial injuries was 36.58 days (95% CI: 29.02–44.15 days), which was shorter than the

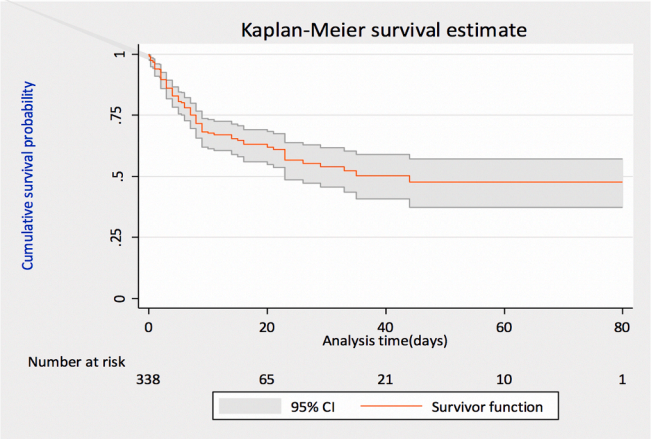

Fig. 1. Overall Kaplan–Meier curve for estimating survival of patients with traumatic brain injury diagnosis at Felegehiwot Comprehensive Specialized Hospital, Bahir Dar, Ethiopia, from January 1, 2015 to December 31, 2019.

Table 3
Results of the bivariate and multivariate Cox proportional hazards regression analyses of traumatic brain injury patients at Felegehiwot Comprehensive Specialized Hospital, Bahir Dar, Ethiopia, from January 1, 2015 to December 31, 2019 ($N = 338$).

Characteristics	Category	Censored	Event	Bivariate CHR (95% CI)	Multivariate AHR (95% CI)
Mode of arrival	On foot	24	1	1	1
	By ambulance	48	33	7.42 (1.05–54.60) *	2.62 (0.19–37.07)
	Private/public service	146	46	4.51 (0.62–32.77)	1.09 (0.08–14.36)
	By stretcher	17	23	11.20 (1.51–83.15) *	1.21 (0.08–17.75)
Mode of injury	RTA	73	54	1.71 (1.00–2.93)	1.54 (0.58–4.12)
	Assault/violence	94	31	1.02 (0.57–1.82)	0.79 (0.41–1.53)
	Fall	68	18	1	1
Type of head injury	Blunt	94	26	1	1
	Penetrating	141	77	1.56 (1.00–2.44)	0.84 (0.37–1.87)
Duration until presentation	< 6 h	126	64	1.93 (1.13–3.30)	0.97 (0.50–1.89)
	6–12 h	31	22	2.45 (1.30–4.63)	0.53 (0.25–1.11)
	>12 h	78	17	1	1
Tracheostomy	No	10	1	1	1
	Yes	225	102	0.14 (0.02–1.01)	1.27 (0.01–1.6)
Pupillary reactivity at admission	Bilateral reactive	163	27	1	1
	Unilateral reactive	29	20	2.69 (1.51–4.80) *	1.48 (0.731–2.98)
	Bilateral nonreactive	43	56	4.34 (2.75–6.90) *	1.99 (1.08–3.71) **
Pupillary reactivity updated	Bilateral reactive	190	13	1	1
	Unilateral reactive	15	11	5.54 (2.48–12.38) *	1.62 (0.48–5.50)
	Bilateral nonreactive	30	79	12.79 (7.1–23.01) *	1.50 (0.57–3.95)
Extra-cranial injuries	Yes	77	51	1.50 (1.02–2.22) *	0.83 (0.51–1.42)
	No	158	52	1	1
Coexisting aspiration pneumonia	No	163	29	1	1
	Yes	72	74	2.81 (1.83–4.33) *	1.24 (0.70–2.59)
Craniotomy	No	150	79	1	1
	Yes	85	24	0.46 (0.29–0.72) *	1.68 (0.67–4.22)
Haematoma evacuation	No	164	67	1	1
	Yes	101	36	0.57 (0.38–0.86) *	0.42 (0.16–0.90) **
Pre-existing comorbidities	No	218	100	1	1
	Yes	17	3	0.46 (0.15–1.45)	0.40 (0.08–2.02)
Basilar skull fracture	No	216	87	1	1
	Yes	19	16	1.97 (1.15–3.36) *	1.15 (0.53–2.50)
Linear skull fracture	No	195	75	1	1
	Yes	40	28	1.52 (0.98–2.35)	1.52 (0.76–3.03)
Subdural haematoma	No	192	92	1	1
	Yes	43	11	0.48 (0.26–0.91) *	0.54 (0.20–1.48)
Intracerebral haematoma	No	216	81	1	1
	Yes	19	22	1.59 (0.99–2.55)	0.73 (0.38–1.4)
Epidural haematoma	No	166	74	1	1
	Yes	69	29	0.75 (0.49–1.16)	0.97 (0. 40–2.34)
Brain concussion	No	229	102	1	1
	Yes	6	1	0.33 (0.05–2.34)	0.94 (0.50–1.77)
Brain contusion	No	142	70	1	1
	Yes	93	33	0.67 (0.43–0.99)	3.99 (0.34–46.69)
Respiratory rate baseline	< 12 bpm	1	1	2.13 (0.28–15.99)	2.03 (0.13–31.09)
	12–20 bpm	38	20	1	1
	> 20 bpm	196	82	0.67 (0.41–1.09	0.76 (0.36–1.57)
Pulse rate updated	< 60	11	10	2.82 (1.40–5.65) *	1.60 (0.60–4.31)
	60–100	190	39	1	1
	>100	34	54	3.53 (2.34–5.33) *	0.81 (0.46–1.44)
SpO_2 at admission	< 90%	178	71	0.752 (0.49–1.143)	0.72 (0.40–1.29)
	90–100%	57	32	1	1
Admission axillary body temperature (°C)	36.5–37.5	104	66	1	1
	< 36.5	100	20	2.33 (1.41–3.84) *	1.75 (0.84–3.66)
	> 37.5	31	17	1.777 (0.93–3.40)	1.50 (0.62–3.67)
Admission systolic blood pressure (mm Hg)	< 90	25	42	1.85 (1.138–3.01) *	1.43 (0.55–3.73)
	90–139	173	48	1	1
	≥ 139	20	30	3.13 (1.98–4.95) *	0.31 (0.11–0.86) **
Updated systolic blood pressure (mm Hg)	< 90	19	39	3.95 (2.61–5.97) *	0.93 (0.42–2.06)
	90–139	19	53	1	1
	≥ 139	17	11	1.96 (1.02–3.76) *	1.16 (0.46–2.91)
Admission diastolic blood pressure (mm Hg)	< 60	98	34	0.92 (0.58–1.46)	0.55 (0.23–1.36)
	60–89	116	40	1	1
	≥ 90	21	29	2.47 (1.53–3.99) *	3.54 (1.33–9.43) **
Updated diastolic blood pressure (mm Hg)	< 60	45	53	3.53 (2.32–5.37) *	1.03 (0.49–2.17)
	60–89	171	37	1	1
	≥ 90	19	13	2.42 (1.29–4.57) *	1.83 (0.59–5.72)
Admission GCS	≤ 8	85	84	7.19 (3.13–16.51) *	4.85(1.73013.62) **
	9–12	51	13	2.92 (1.11–7.69) *	3.25 (1.08–9.77) **
	≥ 13	99	6	1	1

CI, confidence interval; AHR, adjusted hazard ratio; CHR, crude hazard ratio; GCS, Glasgow coma scale; RTA, road traffic accident. *Variables are significantly associated with the outcome according to bivariate analysis at the 95% confidence level.

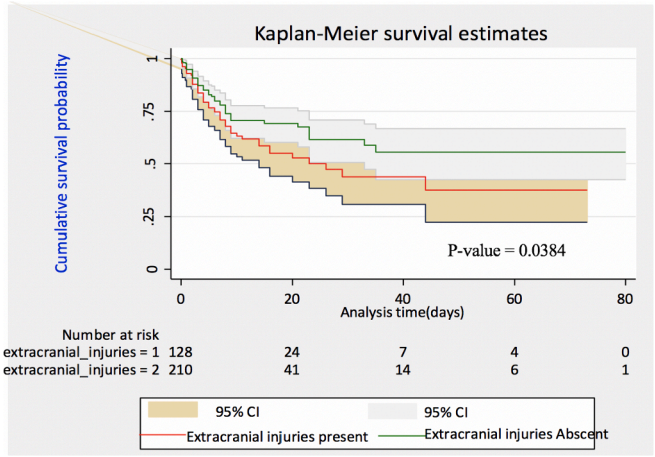

Fig. 2. Kaplan–Meier survival curves comparing the survival time of isolated traumatic brain injury patients versus patients diagnosed with TBI plus extracranial injuries at Felegehiwot Comprehensive Specialized Hospital, Bahir Dar, Ethiopia, from January 1, 2015 to December 31, 2019.

mean survival time of individuals diagnosed with isolated TBI at 49.78 days (95% CI: 42.42–57.15 days). This difference was statistically significant with at $p = 0.0384$ (Fig. 2).

The mean survival time for those who had a severe TBI at baseline was longer than that for those with moderate and severe TBI at 93.27 days (95% CI: 70.34–116.20 days), and this difference was statistically significant at $p < 0.001$ (Fig. 3).

Predictors of mortality

According to the bivariate Cox proportional hazards regression model, the mode of arrival, type of head injury, baseline and updated pupillary reactivity, presence of extracranial injury, co-existence of aspiration pneumonia, craniotomy, haematoma evacuation, tracheostomy, updated respiratory rate, updated pulse rate, both baseline and updated axillary body temperature, and both baseline and updated systolic and diastolic blood pressures were all associated with TBI-related mortality ($p < 0.05$). Variables with $p < 0.25$ by bivariate analysis and non-collinear independent variables were included in the multivariable Cox regression analysis, which showed that TBI patients who had bilateral non-reactive pupils were two times more likely to die compared with patients who had bilateral reactive pupils during admission (adjusted hazard ratio (AHR): 2.00 (95% CI: 1.08–3.71). The hazard of death among those who had elevated diastolic blood pressure at admission was 3.54 times higher compared with those without (AHR = 3.54; 95% CI: 1.33–9.43). The hazard of death among patients with a baseline GCS score at admission ≤8 was 4.85 times higher compared with those with a GCS score ≥ 13 (AHR; 95% CI: 1.73–13.62), and those patients with a baseline GCS score at admission of 9–12 had a 3.25 times greater risk of dying compared with those with a GCS score of 13–15 (AHR: 3.25 (95% CI: 1.08–9.77). Patients who underwent haematoma evacuation had a 66.0% lower risk of death compared with those who did not (AHR: 0.34; 95% CI: 0.16–0.73; Table 3).

Test of assumptions of Cox proportional hazards test

The Cox proportional hazards regression model was used to examine the effects of socio demographic, mode of injury, institutional factors, clinical, and treatment/intervention characteristics for TBI patients on the time to death. The following variables were included in the model as predictors: mode of arrival, mode of injury, haematoma evacuation, craniotomy, baseline pupillary reactivity, updated pupillary reactivity, coexisting medical conditions, extracranial injuries, coexisting aspiration pneumonia, baseline systolic blood pressure, baseline diastolic blood pressure, updated systolic blood pressure, updated diastolic blood pressure, baseline partial pressure of oxygen, and baseline and updated GCS. Goodness-of-fit tests were conducted to statistically assess the assumptions of the Cox proportional hazards model for given predictor variables. The findings indicated that all variables included in the model satisfied the assumptions of the Cox proportional hazards model ($p > 0.05$) except for tracheostomy, and the overall global test result was 0.9651, which is greater than 0.05. Thus, the model was a good fit (Table 3).

Discussion

At the end of follow - up, about 103 patients died and 235 patients were censored, thereby resulting in a cumulative incidence of death of

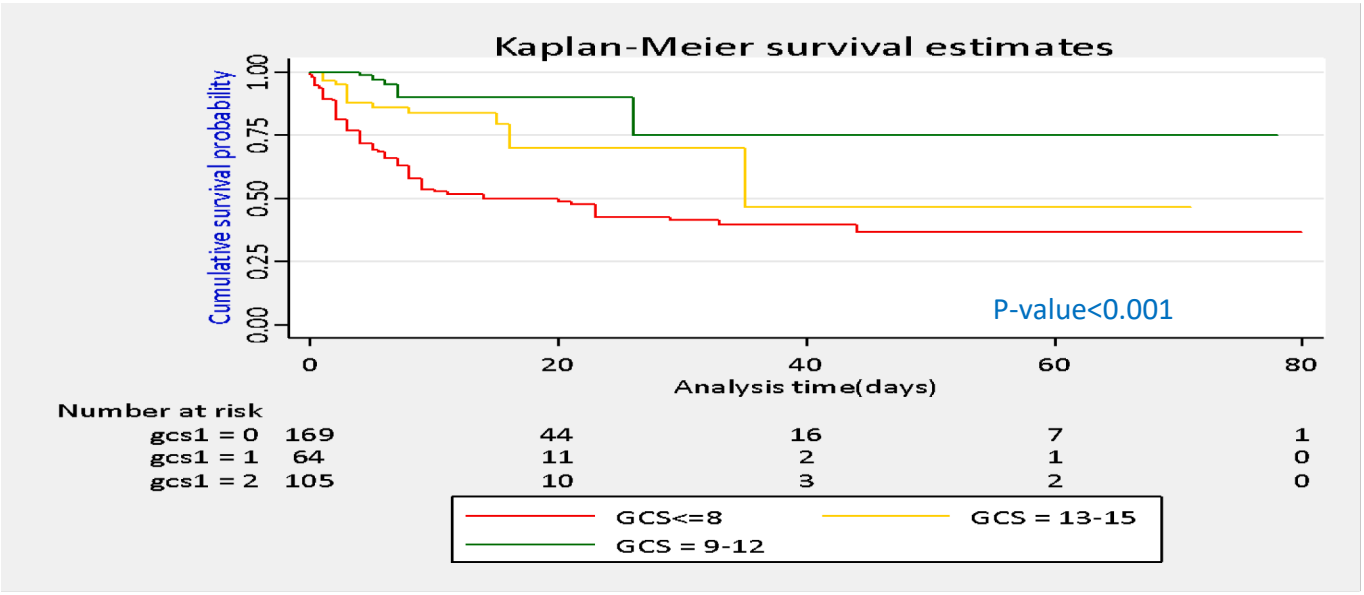

Fig. 3. Kaplan–Meier survival curves comparing the survival time of traumatic brain injury patients with different degrees of severity from baseline diagnoses at Felegehiwot Comprehensive Specialized Hospital, Bahir Dar, Ethiopia, from January 1, 2015 to December 31, 2019.

30.47% after 80 days of follow-up and a mortality rate of 25.3 per 1000 person-days. These findings are similar to the results obtained by a study conducted in Malawi (30.9%) and Qatar (27%) [24,27], but lower compared with a study conducted in Turkey University Hospital (50%) [28] and higher compared with other studies conducted in Ethiopia (2.11% to 21.2%) [21,29]. These differences may have been due to variations in the sampling size and study period.

In the present study, 43.2% of the TBI patients had coexisting aspiration pneumonia, which is much higher compared with other studies conducted among severe TBI patients in Cambridge University Hospitals (3.6%) and Taiwan (29.6%) [30,31]. The high incidence in this study may have been related to inappropriate transportation during referral, or inadequate nursing care with a mechanical ventilator, tracheostomy, oral care, or nasogastric tube [31]. These differences between countries may be attributed to variations in the level of prehospital and hospital care, or the availability of subspecialized physicians, nurses, and anesthesiologists.

In the present study, the cumulative incidence of death among severe TBI patients was 49.71%, which is lower compared with a study conducted at Jimma University Hospital where the mortality rate was 57% [21], but higher compared with a Chinese retrospective study where the mortality among patients admitted to hospital with a GCS score ≤ 8 was 21.8% [32]. The different results obtained in these studies could have been due to differences in the sample size, changes in the treatment modalities, improved patient care, and different practices in intensive care units.

Assault/violence (37.0%) and road traffic accidents (33.4%) were the main causes of admission due to TBI. Similar results were obtained in studies conducted in Turkey and Ethiopia [19,33]. The cumulative incidence rates (mortality) among patients who arrived by stretcher (55.3%) and by ambulance (36.8%) were higher compared with those who arrived by other methods. The high death rate among patients who arrived by stretcher (55.3%) may have been due to the delay secondary to poor infrastructure and the absence of prehospital care. The hazard of death among patients who arrived by ambulance was two times higher compared with that for those who arrived on foot (AHR: 2.012). This high hazard of death might have been related to the severity of the injury at the scene, ambulance service delays, complications during transportation, or the absence of prehospital care. In addition, the mechanism of injury might have been an important factor because most patients were injured in a road traffic accident.

In this study, 338 TBI patients were followed up for a total of 4032.99 days and the median survival time was 44 days. Kaplan–Meier survival curve estimation showed that the overall estimated survival rate after diagnosis with TBI was 47.53% after 4032.99 person-days of observation. The estimated cumulative survival was 75.13% after 1 week of follow-up. This value is higher compared with studies conducted in Norway (24%) and Egypt (36.6%) [34,35]. The estimated cumulative survival was 53.94% after 30 days of follow-up, which is lower compared with a study conducted in a Norwegian university hospital where the cumulative 30-days survival was 83.1% [34]. This discrepancy might be explained by differences in the treatment modalities between Norway and Ethiopia. The cumulative survival rate in this study decreased as the study time increased. This decreased survival may be attributed to the severity of the injury, aggravation of primary brain injury to secondary brain injury, or ineffective treatment.

The median survival time for TBI patients admitted due to blunt head injury was 44 days, which was longer compared with the median survival time for those admitted due to penetrating head injury (23 days). This finding is compatible with the pathophysiology and severity of this type of injury. Among the different TBIs, penetrating brain injury has a worse prognosis [36]. Among 169 (50.0%) TBI patients diagnosed with severe TBI (GCS $\leq$ 8) based on their GCS score at admission, the cumulative survival was 36.92%, and those for patients diagnosed with moderate and mild TBI patients were 46.6% and 75.03%, respectively. The results showed that patients diagnosed with severe TBI had a 2.47 times greater risk of death compared with the patients diagnosed with moderate TBI (Crude HR: 2.47; 95% CI: 1.37–4.428) and a 7.19 times higher risk of death compared with the patients diagnosed with mild TBI (Crude HR: 7.19; 95% CI: 3.13–16.51).

In this study, the GCS score, bilateral non-reactive pupils, elevated systolic and diastolic blood pressures, and haematoma evacuation were identified as significant predictors of TBI-related mortality by multivariable Cox regression analyses. TBI patients with bilateral non-reactive pupils when admitted to FHCSH were two times more likely to die compared with patients who had bilateral reactive pupils during admission (AHR: 2.00; 95% CI: 1.08–3.71). This finding is similar to that obtained by a study conducted in Brazil (adjusted odds ratio: 3.48; 95% CI: 1.03–11.67; $p = 0.04$) [37,36] but lower than that in a study conducted in Spain (adjusted odds ratio: 12.88; 95% CI: 7.45–22.27) [38]. These differences might be explained by advances in management because the study periods were different. A study conducted in Qatar found that TBI patients with extracranial injuries had a greater hazard of death compared with isolated TBI patients according to Cox survival analysis (AHR: 2.4; 95% CI: 1.56–3.70; $p = 0.001$). However, in the present study, the presence of polytrauma was not a predictor of TBI-related mortality according to Multivariable Cox proportional hazards regression analysis (AHR: 0.80; 95% CI: 0.503–1.282), which may be explained by variations in the extracranial injuries and the severity of both TBI and extracranial injuries. In the present study, patients diagnosed with severe TBI (AHR: 4.85; 95% CI: 1.73–13.62) and moderate TBI (AHR: 3.25; 95% CI: 1.08–9.77) based on their GCS scores were more likely to die compared with patients diagnosed with mild TBI according to multivariate Cox proportional hazards regression analysis. Similar results were obtained in studies conducted in Brazil (crude odds ratio: 5.27 (95% CI: 2.72–10.19) [37] and Serbia (crude odds ratio: 2.83; 95% CI: 1.462–5.48) [39].

In the present study, elevated diastolic blood pressure was a significant predictor of mortality (AHR; 3.54; 95% CI: 1.33–9.43). This finding is consistent with pathophysiological evidence following TBI. The initial injury to the brain often increases the intracranial pressure through a local mass effect and diffuse cerebral oedema, and this increase in intracranial pressure leads to a complex interaction with the neuroendocrine response by activating the autonomic system, with the further release of catecholamine. The systemic release of catecholamine often leads to an increase in arterial blood pressure [40–42].

The overall mortality rate in the study cohort was two per 100 person-days of observations and the proportion of death was three per 10 victims of TBI. These findings are relatively high compared with previous studies. The GCS score, bilateral non-reactive pupils, elevated systolic and diastolic blood pressures, and haematoma evacuation were significant predictors of mortality.

It was not possible to determine the effects of residence and occupational status on the survival time and status of TBI patients due to the lack of data. However, some previous studies found that these were important factors that could increase/decrease the survival times of victims and predict mortality. Moreover, the data were collected during the period from January 1, 2015 to December 31, 2019, and they might not reflect current interventions that could affect the survival probability in the study population.

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Dissemination of results

Authors contributed as follow to the conception or design of the work; the acquisition, analysis, or interpretation of data for the work;

and drafting the work or revising it critically for important intellectual content: The findings of the study are submitted to Bahirdar university, college of medicine and health sciences, department of Adult health Nursing. It is disseminated to Felegehiwot comprehensive specialized hospital medical director office, adult ICU, surgical ward and emergency OPD of Felegehiwot comprehensive specialized hospital, Amhara regional Health bureau, Bahirdar-zone health office and to all other concerned bodies who may utilise the findings. It will be presented to different scientific conferences and symposiums. Finally, it is sent for publication in African journal of emergency medicine and critical care nursing to make it accessible to the scientific community. All authors approved the version to be published and agreed to be accountable for all aspects of the work.

Authorship contribution statement

All authors contributed to the design of the study and the interpretation of data. AT performed the data analysis and compiled the study. AT and TD drafted the manuscript. All authors critically revised the draft manuscript. All authors read and approved the final manuscript.

Declaration of competing interest

The authors declare no conflicts of interest.

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