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RESEARCH

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Analysis of moderate and severe traumatic brain injury associated with skull base fracture: a local tertiary center experience

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Abstract

Background Traumatic brain injury (TBI) is a major medical and social concern in developing countries. TBI-related morbidity and mortality statistics in Egypt are lacking and do not reflect the actual magnitude of the problem.

Objectives To overview the incidence of moderate and severe head trauma in a heavily populated developing country and document the outcome of moderate and severe TBI associated with skull base fracture (SBF).

Methodology Data of patients admitted to our center with moderate and severe TBI associated with skull base fracture (SBF) were reviewed in the period between January 2019 and March 2023**.**

Results The most common type of trauma was road traffic accidents in 54.2% of the patients; 91.2% had Single SBF (middle cranial fossa fracture was predominant 58.5%). 25.5% had an initial GCS of ≤ 8. Periorbital ecchymosis was the most common presenting sign in 36.3%. The most frequent complication (37.3%) was pneumocephalus. The presence of skull base fracture inversely affected the Glasgow outcome scale extended GOSE ($P = 0.001$, $r = 0.674$). Higher initial GCS scores were positively correlated with good GOSE (GOSE) ($P = 0.001$, $r = -0.222$).

Conclusions RTA represents a significant cause for moderate and severe TBI in young male population. SBF is associated with poor outcome in moderate and severe TBI. Higher initial GCS score was positively correlated with good GOSE. It is important to have an overview of different types of TBI in Egypt.

Keywords TBI, Moderate and severe, Outcome, Skull base fracture, Predictors

Introduction

Traumatic brain injury (TBI) is a significant medical and social issue in modern society. TBI is frequently encountered in emergency rooms, accounting for over one million visits yearly [1]. Road injuries ranked 10th as a leading cause of mortality in lower-middle-income countries according to 2019 WHO Fact sheets [2]. It is the most common cause of mortality among young people (15–29 years) worldwide [1, 3].

In the United States, the annual incidence of TBI is approximately 500 in 100,000. However, around 80% of all TBI cases categorized as mild head injuries [1]. TBI-related morbidity and mortality statistics in Egypt are lacking and do not reflect the actual magnitude of the problem [4, 5]. Skull base fracture (SBF) occurs in 4%–30% of patients admitted with head injuries [6]. It may be caused by direct impact or propagation of high-energy force through the skull. Common causes of skull base fracture are traffic accidents, falls, assaults, and gunshot wounds.

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The severity of TBI is routinely assessed, following the initial resuscitation and within 48 h of injury, using the Glasgow Coma Scale (GCS), [7]. Many different clinical signs can predict SBF and its location. Diagnosis is confirmed by different modalities of Computerized tomography (CT) [8].

Moderate and severe TBI are primary causes of injury related morbidity and mortality. There is no various statistical analysis of the RTA related head trauma and its complications in Egypt. Rapid population growth and economic reforms are main reasons for high number RTAs [4, 5].

Egyptian healthcare system carries high burden of treating large numbers of trauma patients despite the limited healthcare professional as well as the medical resources in developing countries [9].

The severity of TBI and its subsequent impact on patient outcomes are complex considerations that demand a comprehensive understanding to enhance treatment strategies and improve functional recovery.

Retrospective analysis of relevant data was conducted in a single tertiary care center. Data of Patients with moderate and severe head injury associated with skull base fracture was collected and analyzed. Our research focuses on presenting the outcome of moderate and severe traumatic brain injury (TBI) in patients with SBF.

Materials and methods

Patient population and study design

This is a single tertiary center retrospective cohort study conducted in the Emergency Hospital, Mansoura University, Egypt. The ethical Committee "local Institutional Review Board at Mansoura medical school" approved the study protocol. Data were handled according to Helsinki Declarations of biomedical ethics [10].

Data were extracted from the emergency hospital medical registry between January 2019 and March 2023. The Picture archiving and communication system (PACS was revised for all patients with clinical evidence of SBF. The in-hospital course, including the initial (GCS) and complications, was reviewed using (Ibn-Sina system) to retrieve relevant data.

The total number of trauma patients is about 236,000 per year. In the study period, we received about 6490 patients with TBI. Data of patients with TBI were collected. The severity of trauma was categorized as mild (GCS 13–15), moderate (GCS 9–13) and severe (GCS 3–8) head injuries. SBFs diagnosed by the presence of clinical signs and radiological evidence. SBFs in mild head trauma, polytraumatized patients and those who underwent surgical intervention excluded from the study.

Inclusion criteria included all patients with moderate and severe TBI associated with SBF in the period between January 2019 and March 2023. Out of a total of 6490 traumatic brain-injured patients, 306 fulfilled the inclusion criteria (21.2% of total TBI). The demographic data (gender, age), mode of injury, clinical presentation including level of consciousness assessed by GCS, periorbital bruises "Raccoon's eye," bruising at the posterior auricular region "battle sign," cerebrospinal fluid from the nose "CSF rhinorrhea" and cerebrospinal fluid from the ears "CSF otorrhea" were gathered and analyzed. The modes of trauma were assault by others (struggle), road traffic accident (RTA), falling to the ground (FTG), falling from height (FFH), falling downstairs (FDS) and direct head trauma (DHT).

The patients with clinical evidence of SBF had High resolution CT scan (HRCT) (1 mm cuts) with axial, coronal, and sagittal reconstructions as a diagnostic tool for detecting SBF and its exact location (anterior, middle, or posterior skull base fossa).

Outcome assessment

Clinical outcome was assessed, using Glasgow outcome scale extended (GOSE), in six months post injury.

Statistical analysis and data interpretation

Data analysis was performed using SPSS software (SPSS Inc., PASW statistics for windows, version 25, Chicago). Qualitative data were represented by numbers and percentages. Quantitative data were represented by the median for nonnormally distributed data after testing normality using the Kolmogorov–Smirnov test. Results were considered statistically significant if ≤ 0.05. The Chi-Square test used to compare qualitative data between groups as appropriate. Mann–Whitney U and Kruskal–Wallis test used to compare between two studied groups and more than two studied group–s, respectively, for nonnormally distributed data. Spearman's rank-order correlation determines the strength and direction of a linear relationship between two nonnormally distributed continuous variables and, or ordinal variables.

Results

Three hundred six patients met the inclusion criteria. The demographic data, mode of trauma and types of skull base fractures summarized in Table 1.

The male gender (n = 189, 61.8%) was predominant in our patient series. The most common age group affected was 31–40 years (n = 69 patients, 22.5%) and 21–30 years (n = 62 patients, 20.3%). Road traffic accidents were the most common mode of trauma (n = 166 patients, 54.2%) followed by falling from height (n = 75 patients, 24.5%) (Fig. 1). Single skull base fracture was detected in 279

Table 1 General characteristics of patients with SBF, clinical presentations & complications of SBF associated with moderate & sever TBI

Characteristics	Number of patients = 306	Percentage (%)
Sex: Male Female		
	189	61.8
	117	38.2
Age range (years)		
01-Oct	32	10.5
Nov-20	39	12.7
21–30	62	20.3
31–40	69	22.5
41–50	48	15.7
51–60	32	10.5
61–70	16	5.2
≥ 70	8	2.6
Mechanism of injury: Struggle		
RTA	23	7.5
FTG	166	54.2
FFH	24	7.8
FDS	75	24.5
DHT	15	5
	3	1
Types of SBF		
ACF	75	24.5
MCF	180	58.8
PCF	24	7.9
ACF + MCF	27	8.8
GCS		
≤ 8	78	25.5
Sep-13	228	74.5
Clinical manifestations		
Periorbital ecchymosis	111	36.2
Post-auricular ecchymosis	49	16
CSF Rhinorrhea	36	11.8
CSF otorrhea	95	31
CSF rhinorrhea + otorrhea	15	5
Complications		
No complications	150	48.9
Pneumocephalus	114	37.3
Meningitis	33	10.8
Brain abscess	3	1
Hydrocephalus	6	2

RTA: road traffic accident; FTG: falling to the ground; FFH: falling from height; FDS: falling downstairs; DHT: direct head trauma; ACF: anterior cranial fossa; MCF: middle cranial fossa; PCF: posterior cranial fossa

patients (91.2%), most commonly in the middle fossa (n = 180 patients, 58.8%), (Fig. 2). Multiple skull base fractures involving anterior and middle cranial fossa were encountered in 27 patients, (8.8%).

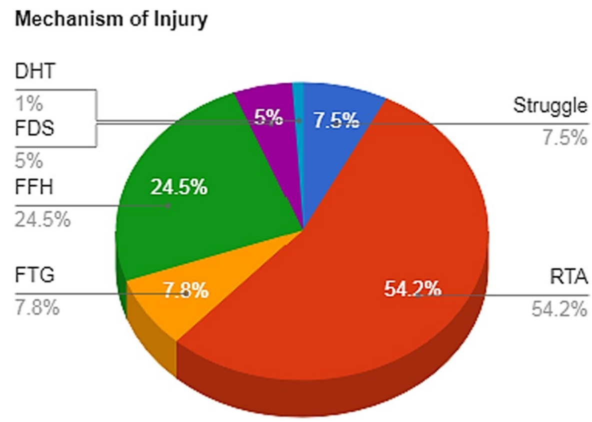

Fig. 1 Distribution of modes of traumatic brain injury

Two hundred twenty-eight patients (74.5%) had moderate head trauma (GCS 9-13); 78 patients (25.5%) had initial GCS (≤8). The most common presenting sign was periorbital ecchymosis (111 patients, 36.3%) (Fig. 3) followed by CSF otorrhea (95 patients, 31%) (Fig. 4), battle sign (49 patients, 16%) and CSF rhinorrhea (36 patients, 11.8%).

One hundred fifty patients (48.9%) had no complications; while, the most common complication was pneumocephalus (114 patients, 37.3%) followed by meningitis in (33 patients, 10.8%), hydrocephalus in (6 patients, 2.0%), and brain abscess in (3 patients, 1.0%) (Table 1).

Chi-square and Fischer exact tests were used to correlate age and gender with mode of trauma and type of skull base fracture. Male gender and age between 31 and 40 groups, were the most affected among all other groups. Road traffic accident was the most common mode of trauma. MCF fracture was the most common type of SBF (Table 2).

Analysis of RTA group revealed that incidence was higher in male gender (n = 112, P < 0.001), most of them (n = 110, P < 0.001) occurred in moderate head trauma group. Middle (n = 91) and posterior cranial fossa fractures (n = 5) had significant statistical correlation to RTA (P value < 0.001) (Table 3).

Single skull base fracture detected in 279 patients (91.2%). 204 patients (73.1%) had initial GCS [9–13]; While 75 patients (26.9%) had initial GCS ≤ 8.

Periorbital ecchymosis (n = 87, 38.2%) and CSF otorrhea (n = 30, 38.5%) was the most common presenting sign in moderate and severe TBI, respectively. Pneumocephalus (n = 114, 37.3%) was the most common complication in both moderate and severe TBI groups (Table 4).

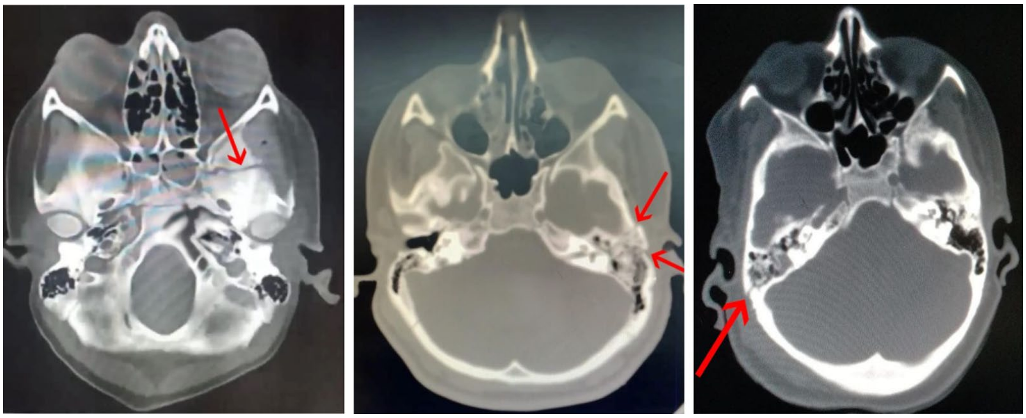

Fig. 2 Middle cranial fossa fractures

Periorbital ecchymosis mainly was observed in ACF Fractures. It occurred in combination with Raccoon's eye sign (MCF fractures) in 24/180 patients. None of the PCF patients showed periorbital ecchymosis. Battle sign was observed in radiologically evident MCF fractures more than PCF fractures. Rhinorrhea and otorrhea were observed more in ACF and MCF fractures, respectively (Table 5). A significant correlation ($P=0.008$) was found between PCF fractures and pneumocephalus (Table 6).

Multivariate Spearman correlation used to identify the correlation between initial GCS and Presence of Skull base fracture (single or Multiple) on extended Glasgow outcome scale (GOSE) and revealed statistically significant correlation between them; GOSE was assessed within 6 months post injury. The presence of skull base fracture was inversely correlated with the GOSE ($P = 0.001$, $r = 0.674$) (Fig. 5). Higher initial GCS score was directly proportionate with good GOSE ($P = 0.001$, $r = -0.222$) (Fig. 6) (Table 5).

Fig. 4 Left ear CSF otorrhea with halo sign

Fig. 3 Bilateral periorbital ecchymosis (Raccoon's eye)

Discussion

Moderate and severe TBI are primary causes of injury related morbidity and mortality. There is not enough statistical analysis of the RTA related head trauma and its complications in Egypt. Large population and progressive economic reform strategies are the main reasons for the increase in number of traffic accidents [4, 5].

The incidence of SBF has been reported to occur in 3.5–45.4% of TBI patients. The majority of these data derived from developed countries. It represented 21.2% of TBI patients in our study [11–14].

Male gender was predominant in our study population matching the results of previous studies [11–14]. Males usually represent the majority of workforce; therefore, they are more susceptible to accidents and subsequent head trauma more than females.

Similar previous studies showed that young population (21–40 years) were the most affected age group in moderate and severe TBI associated with SBF [14, 15]. Our results showed that the age group (31–40) and (21–30) years were the most commonly affected groups. RTA was the most common mode of trauma. Age group (18–30) years is most commonly affected matching previous reports [14–16].

Multi-slice HRCT and other advanced imaging technologies were advocated to detect SBF [8, 17–20]. In contrast, others have emphasized the significance

Table 2 Correlation between mode of trauma & type of fracture in SBF patients and age groups

Age range (years)	1-10y	11–20	21–30	31–40	41–50	51–60	61–70	≥ 70	P value
Male/female (sex ratio)	10/22	12/25	42/20	46/19	41/11	20/10	11/7	07/3	< 0.001*
Mode of trauma (%)									
Struggle	0	0	3	9	8	3	0	0	
RTA	5	21	46	40	30	19	5	0	
FTG	7	1	0	0	0	0	10	6	< 0.001*
FFH	17	15	12	16	12	3	0	0	
FDS	3	0	0	0	1	4	3	4	
DHT	0	0	1	0	1	1	0	0	
Type of fracture									
ACF	7	3	16	15	14	11	6	3	0.003*
MCF	22	16	37	40	32	17	10	6	0.451
PCF	0	14	4	3	2	0	0	1	0.41
ACF + MCF	3	4	5	7	4	2	2	0	0.368

Used test: Chi-square test, *statistically significant, Fisher exact test

Table 3 Stratification of SBF patients According to modes of TBI

	Struggle N = 23 (%)	RTA N = 166 (%)	FTG N = 24 (%)	FFH N = 75 (%)	FDS N = 15 (%)	DHT N = 3 (%)	Total N = 306 (%)	P value
Location (%):								
ACF	9 (39.1)	49 (29.5)	7 (29.2)	19 (25.3)	4 (26.7)	1 (33.33)	75 (24.5)	0.258
MCF	10 (43.5)	91 (54.8)	11 (45.8)	26 (34.7)	8 (53.3)	1 (33.33)	180 (58.8)	< 0.001*
PCF	2 (8.7)	5 (3)	2 (8.3)	7 (9.3)	1 (6.7)	0 (0)	24 (7.9)	< 0.001* 0.362
ACF + MCF	2 (8.7)	21 (12.7)	4 (16.7)	23 (30.7)	2 (13.3)	1 (33.33)	27 (8.8)	
GCS (%)								
≤ 8	8 (34.7)	56 (33.7)	8 (33.3)	4 (5.3)	1 (6.6)	1 (33.3)	78 (25.4)	< 0.001*
Sep-13	15 (65.3)	110 (66.3)	16 (66.6)	71 (94.4)	14 (94.4)	2 (66.6)	228 (74.6)	

Used test: chi-square test, *statistically significant, Fisher exact test

Table 4 Correlation between GCS and Type of skull base fracture & clinical presentation & complications

GCS	≤ 8 N = 78 (%)	Sep-13 N = 228 (%)	Total N = 306 (%)	P value
Type of skull base fracture (%)				
Single fracture	75 (26.9)	204(73.1)	279(91.2)	0.073
Multiple fracture	3 (11.1)	24 (88.9)	27(8.8)	
Clinical manifestations				
Periorbital ecchymosis	24 (30.8)	87 (38.2)	111 (36.3)	< 0.001* 0.001*
Post-auricular ecchymosis	11 (14.1)	38 (16.7)	49 (16)	0.148
CSF Rhinorrhea	7 (9)	29 (12.7)	36 (11.8)	< 0.001*
CSF Otorrhea	30 (38.5)	65 (28.5)	95 (31)	< 0.001*
CSF rhinorrhea + Otorrhea	6 (7.6)	9 (3.9)	15 (4.9)	
Complications				
No complications	39 (50)	111 (48.6)	150 (49)	0.576
Pneumocephalus	27 (34.6)	87 (38.1)	114 (37.3)	< 0.001*
Meningitis	6 (7.6)	27 (11.8)	33 (10.8)	0.399
Brain abscess	0	3 (1.3)	3 (1)	0.573
Hydrocephalus	6 (7.6)	0	6 (1.9)	0.271

(%): percentage of total number of patients. Used test: Chi-Square test, *statistically significant, Fisher exact test

Table 5 Correlation between incidence of CSF leak (otorrhea & rhinorrhea), signs of skull base fracture (Raccoon eye & battle sign) and type of skull base fracture

	ACF *N* = 75	MCF *N* = 180	PCF *N* = 24	ACF + MCF *N* = 27
Raccoon eye *N* = 111 (36.3%)	75 $\chi^2 = 268, \Pi < 0.001$*	24 $\chi^2 = 98.69, \Pi = 0.001$*	0 $\chi^2 = 4.94, \Pi = 0.02$*	12 $\chi^2 = 48.61, \Pi = 0.01$*
Battle sign *N* = 49 (16%)	4 $\chi^2 = 28.69, \Pi < 0.001$	35 $\chi^2 = 47.52, \Pi < 0.001$*	4 $\chi^2 = 8.46, \Pi = 0.004$*	6 $\chi^2 = 32.34, \Pi = 0.002$*
Rhinorrhea. *N* = 36 (11.8%)	22 $\chi2 = 12.24, \Pi < 0.001$*	6 $\chi2 = 12.79, \Pi < 0.001$*	0	8 $\chi2 = 7.341, \Pi = 1.0$
Otorrhea *N* = 95 (31%)	13 $\chi2 = 31.38, \Pi < 0.001$*	66 $\chi2 = 40.26, \Pi < 0.001$*	15 $\chi2 = 7.16, \Pi = 0.003$*	1 $\chi2 = 2.15, \Pi = 0.002$*

χ^2:Chi-Square test, *statistically significant, Sig. = significance, Rhinorr. = Rhinorrhea, Otorr. = Otorrhea

Table 6 Correlation between pneumocephalus and type of skull base fracture (anterior & middle and posterior)

Type of skull base fracture	Total No	Pneumocephalus		Test of significance
		No *N* = 192 (62.5%)	Yes *N* = 114 (37.3%)	
ACF	75	64	11	$\chi^2 = 1.57$, $\pi = 0.210$
MCF	180	102	78	$\chi^2 = 3.03$, $\Pi = 0.082$
PCF	24	9	15	$\chi^2 = 7.10$, $\pi = 0.008$*
ACF + MCF	27	17	10	$\chi^2 = 2.01$, $\Pi = 0.056$

χ^2: chi-square test, *statistically significant

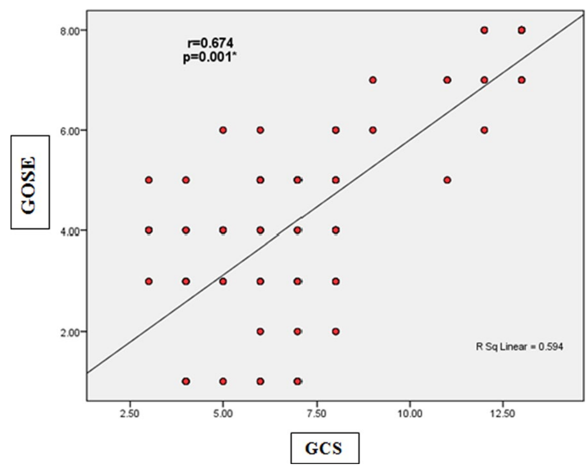

Fig. 6 Correlation between extended Glasgow outcome scale and Glasgow coma scale

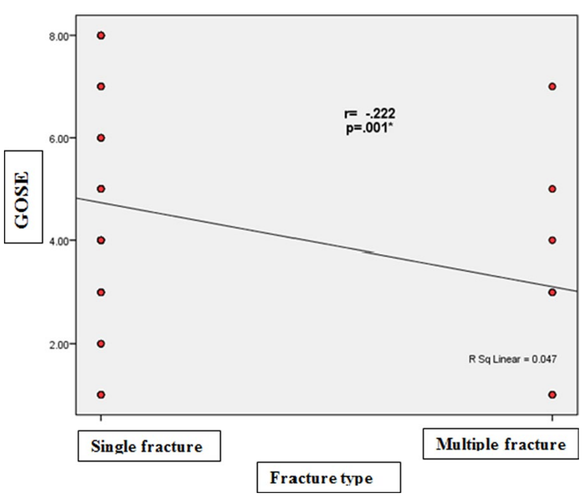

Fig. 5 Correlation between extended Glasgow outcome scale and types of skull base fractures

of clinical signs suggestive of SBF [12, 20, 21]. In our retrospective analysis, HRCT brain was only performed (1 mm thin basal cuts; axial, coronal and sagittal reconstructions) in patients with clinical signs of SBF.

Major neurovascular structures, connecting intracranial and extracranial compartments, pass through skull base. This makes it a dangerous anatomical region for even simple fissure fracture [11, 21, 22]. Our study showed that MCF fractures, detected in 180 patients (58.8%), was the most common type of skull base fractures followed by ACF fractures in 75 patients (24.5%), ACF + MCF fractures in 27 patients (8.8%) then fractures affecting PCF in 24 patients (7.9%). Thinner bone and multiple foramina in MCF, carrying neurovascular bundles, could make it more liable to fractures in comparison with other fossae.

Clinical features of SBF are pathognomonic and include CSF leakage (rhinorrhea, otorrhea), periorbital ecchymosis and postauricular ecchymosis [13, 23, 24].

In our study, periorbital ecchymosis was the most common presenting sign (36.3%) followed by CSF otorrhea, battle sign and CSF rhinorrhea (31%, 16%, 11.8%), respectively.

Post-traumatic CSF leakage (otorrhea and rhinorrhea) is a sign and a complication in the same time. It occurs in 12–30% of all SBF cases and around 2% of all TBI patients [25, 26]. In our study, the prevalence of SBF was 21.2% (306/6490) of all TBI cases; while, CSF leakage was detected in 47.7% (146/306) of SBF patients.

The overall incidence of CSF leakage due to skull base fractures in all TBI patients was 2.24% (146/6490). This requires prompt recognition and early management to guard against meningitis, improve patient outcome, decrease the in-hospital stay and subsequent healthcare burden.

According to the initial GCS presentation, number of patients who had SBF with moderate head trauma was 78 (25.4); while in severe head trauma, the number was 228 (74.6%).There was no statistical correlation ($P=0.073$) between the presence or absence of SBF and the severity of head trauma. Single SBF was found in 279 (91.2%); while, multiple SBFs were found in 27 (8.8%) patients. There was no statistically significant correlation between severity of head trauma and number of skull base fractures ($P=0.073$). Previously published reports showed no correlation between severe head trauma and number of skull base fractures [11].

No complications were detected in 150 patients (49%). Pneumocephalus ($n=114$) was the most common complication (37.3%) followed by meningitis ($n=33$, 10.8%). Six patients (1.9%) had hydrocephalic changes in comparison with previously reported incidence of 0.7% [11]. PCF fracture was correlated with higher incidence of pneumocephalus ($P=0.008$). This can be explained by the presence of the pneumatized mastoid air cells. MCF fractures were second due to previously mentioned nature of this bone. Published reports showed an increase in the incidence of pneumocephalus by 8% if there is a fracture of the skull base; and 41% increase, if the Sella turcica is involved. Pneumocephalus represented about 1% only of all TBI cases [26–29].

In our study, CSF leak increased in MCF and ACF fractures, respectively. The predominance of the MCF fractures in our study sample is a possible explanation. The presence of otorrhea in 66 out of 180 MCF fractures and in 95 patients with CSF otorrhea represented a statistically significant link between the CSF leak and the presence MCF fractures followed by ACF fractures, when compared to other types.

There was no correlation between the CSF leak and meningitis. CSF leak mainly was self-limited or low flow, in addition to the early recognition and management. This might explain the absence of significant correlation.

In our study mortality rate (GOSE = 1) was 43 out of 306 patients (14.1%). This goes in line with other reports from data published that showed the mortality rate (14.9%).

Our study carries several limitations**.** Exclusion of mild head injury might induce a selection bias. Circumstances and management of patients in primary care facilities are not standardized for many reasons. This imposes differences in patients received from surrounding geographical areas. Finally, our study data and results might not be validated in other countries because of the differences in between healthcare systems capability, mode of trauma and patients' demographics.

Conclusion

Assessing the outcome and presenting the magnitude of the burden of the TBI in Egypt is of paramount importance. RTA represents a significant cause for moderate and severe TBI affecting the young male population who are engaging in outdoor activity and represents the primary workforce for Egypt. Skull base fracture is associated with poor outcome in moderate and sever TBI. Good GOSE is directly correlated with higher initial GCS scores. The study might increase the awareness of the burden of TBI on the healthcare system in a limited resources country.

Abbreviations

TBI	Traumatic brain injury
RTAs	Road traffic accidents
GCS	Glasgow coma scale
SBF	Skull base fracture
CSF	Cerebrospinal fluid
HRCT	High resolution CT scan
FTG	Falling to the ground
FFH	Falling from height
FDS	Falling downstairs
DHT	Direct head trauma
PACS system	Patients' radiological investigations record
GOSE	Extended Glasgow outcome scale
ACF	Anterior cranial fossa
MCF	Middle cranial fossa
PCF	Posterior cranial fossa

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Author contributions

Conceptualization contributed by MS, AAM, AMN, AAI, AZ, SS, IS, MS.; methodology and data collection contributed by AAM, AMN, AAI.; validation contributed by MS, AAM, AMN, AAI, AZ, SS, IS, MS; data analyses contributed by MS, AAM, AMN, AAI, AZ, SS, IS, MS.; writing–original draft contributed by MS, AAM, AMN, AAI, AZ, SS, IS, MS.; writing, reviewing and editing contributed by IS, MS.; supervision contributed by MS.

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Availability of data and materials
Data will be available after a reasonable demand.

Declarations

Ethics approval and consent to participate
We obtained IRB from mansoura faculty of medicine. Consent to participate from the patients are included.

Consent for publication
Not applicable.

Competing interests
The authors have no conflicts of interest to declare.

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