Patterns and Outcomes of Patients with Penetrating Head Injury

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ABSTRACT
Background: Penetrating head injuries, whether low or high velocity, are dreadful casualties associated with a high incidence of morbidity and mortality. Immediate radiological examination is mandatory to determine the extent of head penetration, location of the penetrating foreign body and need for surgical intervention.
Objectives: This study aimed to evaluate the incidence of penetrating head injuries among polytraumatized patients and to follow up and determine the different outcomes of patients with penetrating head injuries.
Patients and methods: This was a prospective observational descriptive study included 63 traumatic patients with penetrating head injury who were recruited over 1 year duration starting from November 2019 to October 2020 in Mansoura University Emergency Hospital and El-Sheikh Zayed Specialized Hospital, Egypt.
Results: The mean age in the non-survived group was statistically significantly higher as compared to the survived group. The percentage of missiles (firearm) injuries in the non-survived group was statistically significantly higher as compared to the survived group. The Glasgow Coma Scale (GCS) on admission was statistically significantly lower in the non-survivor group as compared to the survivor group. The percentage of cases with unreactive pupils in the non-survivor group was statistically significantly higher as compared to the survival group. The incidence of subarachnoid hemorrhage, intracerebral hemorrhage and brain laceration was statistically significantly higher in the non-survivors group as compared with survivors group. The length of hospital stay and length of ICU stay were statistically significantly longer in the non-survivors.
Conclusion: Early stabilization of patients with suspected head trauma. All patients with head trauma should undergo brain CT for early assessment of degree of brain affection.
Keywords: Trauma, CT, Penetrating head injuries, ICU.

INTRODUCTION

Trauma-related mortality accounts for 9% of deaths in all age groups and most cases involve blunt injuries. Multiple traumas are the main cause of emergency admission, accounting for approximately 16% of global medical expense **(1)**. Traumatic Brain Injury (TBI) is the leading cause of death in all age group. In various series, the mortality estimated to be about 20–30%. According to severity, the head injuries are 80% mild, 10% are moderate and 10% are severe **(2)**. Penetrating brain injury (PBI) includes all traumatic brain injuries, which are not the result of a blunt mechanism. Although less prevalent than closed head trauma, PBI carries a worse prognosis **(3)**.

In civilian populations, PBIs are mostly caused by high velocity objects, which result in more complex injuries and high mortality. PBI caused by non-missile, low-velocity objects represent a rare pathology among civilians, with better outcome because of more localized primary injury, and is usually caused by violence, accidents, or even suicide attempts **(4)**. The current increase in firearm-related violence and subsequent increase in penetrating head injury remains main concern to neurosurgeons in particular and to the community as a whole **(5)**.

The patterns of intracranial injury in penetrating TBI are not fully characterized, since only 59–70% of patients arriving alive to the hospital are evaluated with a head computed tomography (CT) scan **(6)**. Several prognostic factors are used to predict TBI mortality in the acute phase. The most commonly used indicators are the GCS score, the pupillary light reflex reaction and CT scan findings. In addition, missile track and mechanism of injury also play a significant role in mortality prediction from TBI **(7)**.

The highest-velocity injuries tend to have the worst associated damage. In a study, among 314 individuals who suffered penetrating cranial injuries caused by gunshot wounds, found that 73% succumbed to their injuries at the scene of the incident, and a further 19% ultimately died later. Thus, indicating a total mortality rate of 92%. Perforating injuries have an even worse prognosis **(8)**. People with penetrating head trauma may have complications such as acute respiratory distress syndrome, disseminated intravascular coagulation, and neurogenic pulmonary edema. Up to 50% of patients with penetrating brain injuries get late-onset post-traumatic epilepsy **(9)**.

The aim of the current study was to evaluate the incidence of penetrating head injuries among polytraumatized patients and to follow up and determine the different outcomes of patients with penetrating head injuries.

PATIENT AND METHODS

This was a prospective observational descriptive study included 63 traumatic patients with penetrating head injury who were recruited over 1 year duration starting from November 2019 to October 2020

Received: 24/09/2021
Accepted: 22/11/2021

in Mansoura University Emergency Hospital and El-Sheikh Zayed Specialized Hospital, Egypt.

Inclusion criteria: Trauma patients with penetrating head injuries, age ≥ 18 years, and both genders were included.

Exclusion criteria: Age less than 18 years old, patients who refused to participate the study (or their relatives), patients who didn't complete their treatment at Mansoura University Emergency Hospital or El-Sheikh Zayed Specialized Hospital, patients with minor trauma who don't need admission, and patients arrested at emergency department (ED).

Ethical consideration:

A written informed consent was obtained from every participant or their relatives/guardians before inclusion in the study. An approval of the study was obtained from Mansoura University Academic and Ethical Committee. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

All patients were subjected to the following:

- **The primary survey:**

The initial resuscitation occurred concurrently with primary assessment. When a life-threatening condition is found, immediate corrective actions must be taken, and its effects were evaluated before moving on to the next step. The primary assessment should proceed with using the "ABCDE" approach:

- **A. Airway and cervical Spine.**
- **B. Breathing and ventilation.**
- **C. Circulation and bleeding control.**
- **D. Disability and neurologic assessment.**
- **E. Exposure and environment control.**

To complete the 1ry survey & resuscitation: (1) Electrocardiography (ECG). (2) Insertion of urine catheter (urine output, color) if it was not contraindicated. (3) Nasogastric tube if indicated.

- **The secondary survey:**

I. After initial resuscitation effort, all patients were subjected to full history taking including age, gender, mode and time of trauma, time of arrival and resuscitation.

II. AMPLE History taking:

A = **A**llergies
M = **M**edication currently used.
P = **P**ast illnesses/**P**regnancy.
L = **L**ast meal.
E = **E**vents/**E**nvironment related to injury.

III. Clinical examination of the patients at the trauma room including:

1) **Vital signs:** Pulse: bradycardia with increased intracranial pressure (ICP) as a part of Cushing's triad, blood pressure, and respiratory rate and pattern:
2) **Local examination:** Signs of skull fracture, and scalp examination.
3) **Neurological examination:** (i) GCS: Used to define the level of consciousness. Used to assess the severity of TBI. Must be reassessed after full resuscitation and before any sedative or paralytic agents' administration. (ii) Examination for lateralization signs: Limbs examination, and Eye examination. (iii) Complete general examination: head-to-toe examination to define other associated or occult injuries.

IV. Laboratory Investigations: Complete blood count. Blood urea (mg/dl), serum creatinine (mg/dl), serum sodium (mmol/l), and serum potassium (mmol/l). Serum albumin and random blood glucose (mg/dl), and arterial blood gases (with calculation of base deficit).

V. Radiological investigations:

1. **Focused Assessment with Sonography for Trauma (FAST scan):** The primary objective of FAST is to identify the presence of haemoperitoneum in a patient with suspected intra-abdominal injury.
2. **X-ray:** Chest, pelvis, spinal and extremities: Anteroposterior and lateral view as possible.
3. **CT brain:**
   - By using Toshiba scanner Aquilion Prime TSX-303A (164-MCCT scanner) with reconstruction at 0.5 mm slice thickness.
   - To identify any of the following lesions: Fissure fracture of the skull. Depressed fracture of the skull. Brain edema. Diffuse Axonal Injury (DAI). Subarachnoid hemorrhage (SAH). Extra-dural hematoma (EDH). Intra-ventricular hemorrhage (IVH). Intracerebral hematoma (ICH), and Brain contusion and laceration.

Follow up of the cases:

1. **Surgical variables:** Type of surgery, and time elapsed from accident to surgery.
2. **Surgical procedures:** Decompressive craniotomy in case of increased intracranial pressure, and elevation of depressed fracture and cleaning to prevent infection and for cosmetic causes.
3. **The following were assessed (postoperatively after follow up CT scan):** Residual of any pathology, and need for re-operation.
4. **Postoperative treatment:** Based on the conditions of intracranial pressure after operation, Mannitol (0.5 mg/kg), Lasix (0.25 mg/kg), were given. Prophylactic antiepileptic, antibiotics, hemostatic, and neurotropic drugs were routinely used for all the patients.

Statistical analysis

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for Social Sciences) version 26 for Windows® (SPSS Inc, Chicago, IL, USA). Data were tested for normal distribution using the Shapiro Walk test. Qualitative data were represented as frequencies and relative percentages. Chi square test (χ^2) and Fisher exact was used to calculate difference between qualitative variables as indicated. Quantitative data were expressed as mean ± SD (Standard deviation). Independent samples t-test was used to compare between two independent groups of normally distributed variables (parametric data) while Mann Whitney U test was used for non-normally distributed data (non-parametric data). P value ≤ 0.05 was considered significant.

RESULTS

The study included 63 cases with injuries due to traumatic brain injuries. There were 52 males (82.5%) and 11 females (17.5%) with mean age of 38.34 ± 15.1 years with range between 18 and 79 years. The assault was the most common mode of trauma in the included cases (52.4%), accidental injuries in 12 cases (19.1%), road traffic accidents in 11 cases (17.4%) and falling on sharp objects in 7 cases (11.1%). The missiles (firearm) injuries were responsible for traumatic brain injuries in 74.6% of the cases while non-missiles injuries occurred in 25.4% of the cases (Table 1).

Table (1): Demographic data, mode and trauma and cause of trauma in the cases included in the study (n=63)

Age (years)		
Mean ± SD	38.34 ± 15.1	
Median (Min-Max)	36 (18-79)	
	Frequency	**Percentage**
Gender		
Male	52	82.5 %
Female	11	17.5 %
Mode of the trauma		
Assault	33	52.4 %
Accidental	12	19.1 %
Road traffic accidents	11	17.4 %
Falling on sharp objects	7	11.1 %
Cause of the trauma		
Missiles (Firearm)	47	74.6 %
Non-missiles	16	25.4 %

The different types of skull fractures showed that bevelling (bullet inlet and/or exit) in 74.6% of the cases, depressed fractures in 49.2% of the cases, fissure fracture in 23.8% of the cases, skull base fracture in 17.5% of the cases and diastatic fracture in 11.1% of the cases.

The CT brain findings in the cases in the study. Epidural haemorrhage was detected in 58.7% of the cases, subarachnoid haemorrhage in 53.9% of the cases, intracerebral haemorrhage in 26.9% of the cases, Intraventricular haemorrhage in 20.6%, brain edema in 93.7% of the cases and brain laceration in 87.3% (Table 2).

Table (2): Analysis of types of skull fracture and CT brain findings in the cases included in the study (n=63)

	Frequency	**Percentage**
Type of skull fractures		
Bevelling (bullet inlet and/or exit)	47	74.6 %
Depressed fractures	31	49.2 %
Fissure fracture	15	23.8 %
Skull base fracture	11	17.5 %
Diastatic fracture	7	11.1 %
CT brain findings		
Epidural haemorrhage	37	58.7 %
Subarachnoid haemorrhage	34	53.9 %
Intracerebellar haemorrhage	17	26.9 %
Intraventricular haemorrhage	13	20.6 %
Brain edema	59	93.7 %
Brain laceration	36	57.1 %

Among the included cases, GCS was ≤ 8 in 41.3% of the cases, GCS was between 9 and 12 in 33.3% of the cases and GCS was between 13 and 15 in 25.4% of the cases.

Regarding the outcomes in the included cases, surgical interference was required in 31.7% of the cases. Among the included cases, 31 cases (49.2%) survived and 32 cases (50.8%) died. According to GOS, GOS I was present in 32 cases (50.8%), GOS III in 6 cases (9.5%), GOS IV in 5 cases (7.9%) and GOS V in 20 cases (31.7%) (Table 3).

Table (3): Classification of the cases according to GCS and outcomes in the cases included in study (n=63)

	Frequency	Percentage
Cause of the trauma		
GCS ≤ 8	26	41.3 %
GCS 9-12	21	33.3 %
GCS 13-15	16	25.4%
Outcomes		
Surgical interference		
Yes	20	31.7 %
No	43	68.3 %
Survival		
Survived	31	49.2 %
Died	32	50.8 %
GOS		
GOS I	32	50.8 %
GOS III	6	9.5 %
GOS IV	5	7.9%
GOS V	20	31.7 %

The mean age of the non-survived group was 43.9 ± 8.27 years that was statistically significantly higher as compared to the survived group (35.28 ± 7.61years). Males represented 81.3% and 83.9% in the non-survivors and survivor groups respectively with no statistically significant difference. There was high statistically significant difference in the cause of trauma between the cases in the non-survivors group and survivors group (p < 0.001). Missiles (firearm) injuries represented 87.5% of the non-survivor group while it represented 61.3% of the survivor group (Table 4).

Table (4): Demographic data and comparison of the cause of trauma in the cases according to survival

	Group I (non-survivors) (n=32)	Group II (survivors) (n=31)	P value
Age (years)	43.9 ± 8.27	35.28 ± 7.61	< 0.001*
Sex: N (%)			
-Male	26 (81.3%)	26 (83.9%)	0.363
-Female	6 (18.7%)	5 (16.1%)	
Missiles (Firearm)	28 (87.5%)	19 (61.3%)	< 0.001*
Non-missiles	4 (12.5%)	12 (38.7%)	

The GCS on admission was statistically significantly lower in the non-survivor group as compared to the survivor group (p < 0.001). The mean ISS in the non-survivor group was 45.2 ± 15.1 that was statistically significantly higher as compared to the survivors (37.7 ± 13.5) (p=0.005). The median APACHE II score in the non-survivor group was 24 with range between 7 and 41, while in the survivor group was 18 with range between 4 and 38 with statistically significant difference between the two groups (0.011). The MAP was statistically significant lower in the non-survivor group as compared to the survivor group (p < 0.001). The percentage of cases with unreactive pupils in the non-survivor group was 65.6%, which was statistically significantly higher as compared to the survival group (25.8%) (p < 0.001) (Table 5).

Table (5): Analysis of items of general examination on admission in the cases according to survival

	Group I (non-survivors) (n=32)		Group II (survivors) (n=31)		P value
GCS	9 (3-13)		13(8-15)		< 0.001*
ISS	45.2 ± 15.1		37.7 ±13.5		0.005*
APACHE II score	24 (7-41)		18 (4-38)		0.011*
Pulse	90.34 ± 19.48		82.14 ± 21.17		0.096
MAP	81.64 ± 23.09		94.33 ± 25.68		< 0.001*
Pupils					
Unreactive	21	65.6%	8	25.8%	< 0.001*
Reactive	11	34.4%	23	74.2%	

The incidence of subarachnoid haemorrhage, intracerebellar haemorrhage and brain laceration was statistically significantly higher in the non-survivors groups compared with the survivors group (p < 0.001) for all. On the other hand, the incidence of epidural haemorrhage, intraventricular haemorrhage and brain oedema showed no significant difference between the two groups (Table 6).

Table (6): Comparison of the CT brain findings in the cases according to survival

	Group I (non-survivors) (n=32)		Group II (survivors) (n=31)		P value
Epidural haemorrhage	18	56.3%	19	61.3%	0.360
Subarachnoid haemorrhage	23	71.9%	11	35.4%	< 0.001*
Intracerebellar haemorrhage	12	37.5%	5	16.1%	< 0.001*
Intraventricular haemorrhage	8	25%	5	16.1%	0.108
Brain oedema	31	96.9%	28	90.3%	0.215
Brain laceration	25	78.1 %	11	35.4 %	< 0.001*

The length of hospital stay and length of ICU stay were statistically significantly longer in the non-survivors (p < 0.001). The percentage of cases that required mechanical ventilation was statistically significantly higher in the non-survivor group (p<0.001). The requirement for surgical interference didn't show a statistically significant difference between the two groups (Table 7).

Table (7): Analysis of outcome variables in the cases according to survival

	Group I (non-survivors) (n=32)	Group II (survivors) (n=31)	P value
Surgical interference	9 (28.1%)	11 (35.5%)	0.136
Length of ICU stay	8 (3-12)	2 (1-7)	< 0.001*
Length of hospital stay	12 (5-19)	3 (1 - 10)	< 0.001*
Requirement for mechanical ventilation	13 (72.2%)	6 (27.7%)	< 0.001*

DISCUSSION:

In this study, there were 52 males (82.5%) and 11 females (17.5%) with mean age of 38.34 ± 15.1 years with range between 18 and 79 years. This comes in agreement with the results reported by **Vasconcelos and Ribeiro** [10] who revealed that most of traumatic head injuries victims were males due to their challenging behavior, with more involvement in high-risk activities. In another study, it included larger number of patients (1342 consecutive cases were analyzed). The average age was 65.6 ± 20.5 years. Of the patients, 629 (46.9%) were men [11].

In this study, the assault was the most common mode of trauma in the included cases (52.4%), accidental injuries in 12 cases (19.1%), road traffic accidents in 11 cases (17.4%) and falling on sharp objects in 7 cases (11.1%). The missiles (firearm) injuries were responsible for traumatic brain injuries in 74.6% of the cases while non-missiles injuries occurred in 25.4% of the cases. This comes in agreement with **El-Shanawany *et al.*** [12] who included 24 (80%) patients sustained firearm injury, majority of them 20/24 (83.33%) had injury as a result of assault whereas 4/24 (16.66%) had accidental injury. Non missile injuries occurred in 6 patients (20%) assault in half cases and accidental in the other half.

In this study, the GCS of most of the cases indicated good condition of the cases as follows; GCS was ≤ 8 in 41.3% of the cases, GCS was between 9 and 12 in 33.3% of the cases and GCS was between 13 and 15 in 25.4% of the cases. This comes in agreement with the results of another study conducted by **Macciocchi *et al.*** [13] where GCS total scores ranged from 3 to 15, with the most common scores being 13 to 15 (47%). GCS total scores were unknown or not administered in a high number of cases (42%). Opposite results were reported by **Ahuja and his colleagues** [14] where 71% of the cases had GCS less than 8 and 27% had GCS between 8 and 13. In another study, 50% of the cases at the time of admission had a Glasgow Coma Scale (GCS) score of less than 8 and 40% had between 8 and 13. This signifies severity of the injury at the time of presentation. Poor GCS score is associated with worse prognosis [15].

Also in this study, the pupils were unreactive in 29 cases (46.1%) and were reactive in 34 cases (53.9%). In this study, epidural haemorrhage was detected in 58.7% of the cases, subarachnoid haemorrhage in 53.9% of the cases, intracerebral haemorrhage in 26.9% of the cases, intraventricular haemorrhage in 20.6%, brain edema in 93.7% of the cases and brain laceration in 87.3%. **Ahuja *et al.*** [14] showed in their study that most injuries were cerebral contusion- 33 (47%) patients, 10 (14%) had EDH and 17 (24%) patients had SDH. **Wagner *et al.*** [16] reported that most of the injuries were cerebral contusions and/or subdural hematomas with a high mortality rate. **Hassan and his colleagues** [17] reported that SAH (24%) was the major CT finding followed by depressed skull fracture in 23% cases.

Regarding the overall mortality, 31 cases (49.2%) survived and 32 cases (50.8%) died. There was variation in the incidence of mortality following penetrating brain injuries among the different studies. This agrees with those reported by **Fathalla *et al.*** [18] who performed a retrospective review of 102 patients with penetrating military missile head injuries in various facilities in northern Sinai between 2011 and 2018. In that study, the mortality rate was 49%. 11.8% of patients had a persistent vegetative state, and 39.2% of survivors had varying degrees of disability at the final follow-up. In a recent Egyptian study, **El-Shanawany *et al.*** [12] reported that among the cases included, 12 cases (40%) died.

Also in this study, GOS I was present in 32 cases (50.8%), GOS III in 6 cases (9.5%), GOS IV in 5 cases (7.9%) and GOS V in 20 cases (31.7%). This agrees with **Liew *et al.*** [19] who showed in their study that 61 (85%) patients were discharged from hospital, with 29 (40%) having good outcome (GOS 4 and 5). Also this was in accordance with another study where only 40 (37.4%) of patients in the study had a Glasgow outcome score of 4 and 5 [14].

In the current study, the mean age of the non-survived group was 43.9 ± 8.27 years that was statistically significantly higher as compared to the survived group (35.28 ± 7.61 years). In other studies, as **Hofbauer *et al.*** [20]**, Petridis *et al.*** [21] and **Ambrosi *et al.*** [22] it was found that the younger the age of the patient, the better the outcome. So, they considered the age as an important predictor of the outcome.

In the current study, the GCS on admission was statistically significant lower in the non-survivor group as compared to the survivor group (p < 0.001). Our results come in agreement with **Sirko *et al.*** [23] who showed that GCS score on admission is a predictor. Mortality was 44.7% in patients with GCS score of ≤ 8 on admission, whereas it was 5.4% in patients with GCS score of ≥ 9 on admission (P < 0.001). The average GCS score in deceased patients was 5.1 ± 2.68.

In the current study, the MAP was statistically significant lower in the non-survivor group as compared to the survivor group (p < 0.001). Similar results and conclusions were shown by **Sartorius *et al.*** [24] and **Ahn *et al.*** [25] where they reported that the continuous increase in mortality as systolic arterial blood pressure decreased has been recognized.

In the current study, there was high statistically significant difference in the cause of trauma between the cases in the non-survivors group and survivors group (p < 0.001). Missiles (firearm) injuries represent 87.5% of the non-survivor group while it represented 61.3% of the survivor group. This agrees with **El-Shanawany *et al.*** [12] who reported that missile injuries carry a worse prognosis than non-missile injuries as demonstrated by high mortality 45.8% to 16.6% respectively and that missile injuries carries a high incidence of morbidity to non-missile injuries. **Sirko *et al.*** [23] also confirmed that patients with penetrating brain injury secondary to gunshot wound in our cohort had worse functional outcomes at all-time points than those who had blast penetrating brain injury.

In the current study, the incidence of subarachnoid haemorrhage, intracerebellar haemorrhage and brain laceration was statistically significantly higher in the non-survivors group than in survivors group (p< 0.001). On the other hand, the incidence of epidural haemorrhage, intraventricular haemorrhage and brain oedema didn't reveal a statistically significant difference between the two groups. **Kim *et al.*** [26] reported mortality as high as 66.7% in patients with bilobar or multilobar injuries. Penetrating injuries that cross midline have a particularly high mortality rate of approximately 85% compared to multilobar involvement that does not cross midline of 35% [27]. Similar findings were reported by **Hofbauer *et al.*** [20], **Petridis *et al.*** [21] and **Ambrosi *et al.*** [22] where patients with less structural destruction of the brain parenchyma do better functionally over the long term.

CONCLUSION

Penetrating head injuries are serious injuries, which carry a high morbidity and mortality. Gunshot injuries to the head in particular carry a poor prognosis. CT plays an important role in the initial evaluation of stable patients in determining the entry and exit wounds and extent of injury. The treatment of these patients is highly variable and often is determined on a case-by-case basis.

RECOMMENDATIONS

Early stabilization of patients with suspected head trauma. All patients with head trauma should undergo brain CT for early assessment of degree of brain affection. Strict observation and follow up of patients with head trauma with positive findings on initial assessment.

Financial support and sponsorship: Nil.
Conflict of interest: Nil.

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