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SNI: Trauma

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Original Article

Civilian penetrating traumatic brain injury: A 5-year single-center experience

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Received : 23 December 2022
Accepted : 10 January 2023
Published : 27 January 2023

DOI
10.25259/SNI_1160_2022

Quick Response Code:

ABSTRACT

Background: The aim of this study was to report the demographics and clinical features of patients with penetrating traumatic brain injury (PTBI) during the past 5 years in Rajaee Hospital, a tertiary referral trauma center in Shiraz, southern Iran.

Methods: We conducted a 5-year retrospective evaluation of all patients diagnosed with PTBI who were referred to Rajaee Hospital. We retrieved the following items from the hospital's database and PACS system: patients' demographics, on-admission Glasgow Coma Scale (GCS), presence of trauma to other organs, duration of the hospital and ICU stay, the neurosurgical interventions, any necessity of tracheostomy, duration of ventilator dependency, the entrance point of the trauma in the skull, type of assault, length of trajectory in the brain parenchyma, the number of remaining objects in the brain, the occurrence of any hemorrhagic phenomenon, the cross of the bullet from the midline or coronal suture, and the presence of the pneumocephalus.

Results: A total of 59 patients with a mean age of 28.75 ± 9.40 had PTBI over the 5 years. The mortality rate was 8.5%. Stab wounds, shotguns, gunshots, and airguns were the cause of injury in 33 (56%), 14 (23.7%), 10 (17%), and 2 (3.4%) patients, respectively. The median initial GCS of patients was 15 (3–15). Intracranial hemorrhage was observed in 33 cases, subdural hematoma in 18 cases, intraventricular hemorrhage in eight cases, and subarachnoid hemorrhage in four cases. The mean duration of hospitalization was 10.05 ± 10.75 (ranging from 1 to 62 days). Furthermore, 43 patients experienced ICU admission with mean days of 6.5 ± 5.62 (1–23). The temporal and frontal regions were the most common entrance points, in 23 and 19 patients, respectively.

Conclusion: The incidence of PTBI is relatively low in our center, possibly due to the prohibition of possession or using warm weapons in Iran. Further, multicenter studies with larger sample sizes are needed to determine prognostic factors associated with worse clinical outcomes after PTBI.

Keywords: Gunshot, Penetrating traumatic brain injury, Shotgun, Stab wound, Traumatic brain injury

INTRODUCTION

Traumatic brain injury (TBI) is considered a leading cause of morbidity and mortality in different societies, like Iran.[23] According to reports, 2.5 million emergency department visits were recorded in the USA due to the TBI.[7,10]

In Iran, like most of the other regions, the most common underlying cause of TBI is transport accidents, in a way that according to the study, held in our center, 6390 potential years of life lost following TBI were recorded in 2013.[13]

Penetrating TBI (PTBI) represents 0.4–1.5% of all TBI cases, but it is believed to cause the highest rate of mortality among TBI patients (up to 42% of TBI-related mortalities).[7,22]

The majority of PTBI reports reflect the war experiences which are mostly caused by high-velocity missiles and there are not many reports about civilian-based PTBIs in the literature.[27,33]

The pattern of involvement and piercing objects vary worldwide. In the US, where possession of firearms is not illegal, the annual number of gunshot victims reaches 70/000 cases, which leads up to 30/000 deaths and it is estimated that the target in 14% of all gunshot wounds (GSW) is the brain. It is also believed that the global mortality rate following firearm assaults is increasing.[2,4]

There are not many reports on the other etiologies of PTBI, such as the shotgun and stab assaults, as there are on gunshots. As a result, the clinical outcomes following PTBI are not favorable in most reports (because they mostly are about gunshots), in a way that a survival rate of 7–15% has been reported after a gunshot to the brain.[8,10,14]

The aim of the present study is to report the etiology, radiological, and hospitalization characteristics of patients who were admitted to Rajaee Hospital, a tertiary referral trauma center in southern Iran, with the diagnosis of PTBI during the past 5 years.

MATERIALS AND METHODS

All of the patients who were referred to the emergency room of the Rajaee Hospital, a tertiary referral trauma center in Shiraz, southern Iran, with the diagnosis of penetrating brain injury, during the past 5 years were included in the present study.

Patients who passed away before hospital arrival or obtaining brain imaging were excluded from this study. Hospitalization and imaging records of the patients were extracted from the hospital's database and PACS system. By reviewing the obtained brain CT scans, the entrance point, type of assault, length of trajectory, the number of the remaining objects, the occurrence of any hemorrhagic phenomenon, the cross of the bullet from the midline or coronal suture, and the presence of the pneumocephalus were surveyed. The assessment of the injury to the vessels was also conducted by evaluating the CT angiography of the patients.

The information regarding patients' demographics, on-admission Glasgow Coma Scale (GCS), presence of trauma to other organs, duration of the hospital and ICU stay, the neurosurgical interventions, any necessity of tracheostomy, and duration of ventilator dependency were also extracted from the hospitalization records of the patients.

The present study has been approved by the ethics committee of Shiraz University of Medical Sciences and informed consent has been obtained from the patients and their families for inclusion in this report.

Hospitalization

Based on the findings of the initial brain CT scan, the decision for further interventions was made. Patients were admitted to the ICU when they had significant intracranial hemorrhage (ICH), severe injury to other organs, and on admission GCS of lower than 10.

In cases with suspicion of vascular injury, a brain CT angiography was also obtained.

Cranioplasty and dural repair were performed when indicated, and the removal of the foreign bodies was also conducted when objects were not located in deep-seated or eloquent areas.

In cases with findings in favor of a midline shift of more than 5 mm or raised intracranial pressure, decompressive craniectomy was performed. Following the surgical intervention, patients were transferred to the ICU and then, once they were stable, to the ward.

RESULTS

Of the 59 patients diagnosed with penetrating brain injury, 65 patients were male, and the overall mean age was 28.75 ± 9.40.

In 10 (17%) patients, the gunshot was the cause of injury, in 14 (23.7%) shotguns, in 33 (56%) stab wounds, and in two patients (3.4%) air guns. All patients affected by firearms, were injured by civilian types, rather than military weapons, and as a result, these types of injuries were considered as low velocity ones.

Thirty-six cases had also injuries to other organs.

The midline cross was observed in four patients, the cross from coronal suture in 14 patients, and the through and through phenomenon in four cases. The mean length of assault trajectory in the brain parenchyma was 21.49 ± 19.3 mm.

ICH was observed in 33 cases, subdural hemorrhage in 18 cases, intraventricular hemorrhage in eight cases, and subarachnoid hemorrhage in four cases. No hemorrhagic phenomenon was observed in 17 cases. The mean volume of the ICH volume was 13.48 ± 14.2.

The severity of the injury was classified regarding the on-admission GCS of the patients, which is as follows: 1. GCS <8 was categorized as severe, 2. GCS score between 9 and 12 as moderate, and 3. A score of higher than 12 as mild TBI.

The details of the patient's characteristics and imaging findings are provided in [Table 1].

Table 1: On-admission, hospitalization, and imaging characteristics of the patients.

On admission characteristics	Item	Mean (range)/ Number (percent)	
	Cases	59	
	Age	28.75±9.40	
	Initial GCS	11.4 (3–15)	
		Median 15	
	GCS		
	Mild	35 (59.3%)	
	Moderate	4 (6.8%)	
	Severe	20 (33.9%)	
	Blood Pressure		
	SBP	122±16.5 (55–170)	
	DBP	75±12.6 (31–111)	
	Cases with trauma to other organs	36 (61%)	
Imaging findings	Cases with pneumocephalus	22 (37.3%)	
	Depth of tract	21.49±28.03	
	Cases with assaults crossed over midline	4 (6.8%)	
	Cases with assaults crossed over coronal suture	14 (23.7%)	
	Cases with through and through assaults	4 (6.8%)	
	Cases with assaults having ricochet	3 (5%)	
	Cases with vascular injury	12	
Course of hospitalization	Days of hospitalization	10.05±10.75 (1–62)	
	Cases with ICU admission	43	
	Days of ICU stay	6.5±5.62 (1–23)	
	Cases with dependency to ventilator	28	
	Days of ventilator dependency	4.17±3.01	
	Cases needing tracheostomy	7 (11.9%)	
	Performed LP	6 (10.2%)	
	Mortalities	5 (8.5%)	
Entrance point	Region	Left	Right
	Frontal	12	7
	Temporal	17	6
	Occipital	4	-
	Parietal	2	3
	Orbital	6	
	Submandibular	2	

DBP: Diastolic blood pressure, GCS: Glasgow coma scale, ICU: Intensive care unit, LP: Lumbar puncture, SBP: Systolic blood pressure

DISCUSSION

PTBI is defined as an injury to the craniocerebral structures caused by sharp objects with subsequent damage along the trajectory of the piercing insults.[24,31] PTBI accounted for only 0.4% of all TBIs and based on the setting of occurrence could be categorized into two extended groups: military caused by high-velocity or blast injuries and civilian PTBI (caused by a mixture of high-to-low-velocity injuries).[31] The literature is scant regarding the features of civilian PTBI.[24,33] Therefore, the current cross-sectional and registry-based study described the demographic and clinical characteristics of patients with PTBI. We have excluded those who were not alive on hospital arrival or passed away before any documented CT imaging.

It is believed that PTBI has worse clinical outcomes than close blunt head trauma. The overall mortality rate has been reported to vary widely from 34% to 92% in different studies.[5,10,29,33] Such a high mortality rate is still a significant challenge worldwide. D'Agostino *et al.* performed a secondary analysis of a multicentric study of patients with PTBI who survived more than 72 h after hospital admission to investigate whether the surgical intervention improves the outcomes. They have shown that 48.2% of patients with GCS 3–5 and 8% with GCS>6 died following PTBI.[5] In our study, only five patients (8.5%) with PTBI died. They all presented to our center with severe TBI following gunshot (two cases) or shotgun injuries (three cases). CT angiography was done in two of these patients showing injuries to bilateral PICA and MCA + PA in another patient.

The low mortality rate did not let us conduct the prognostic statistical analysis; however, by reviewing the literature, several factors are attributed to this rate.

In our study, the mean age was 28.75 years old which was younger than the reported series from Egypt[33] (a prospective descriptive of 63 patients: age 38.34 ± 15.1), and the US (a retrospective of 26,871 patients with a mean age of 36.2 ± 18)[27] studies. The previous surveys agreed that younger age is a prognostic factor for improved survival rate.[3] Deng *et al.* reported a decrease in the mortality rate in younger fire-arm-related victims in the US. The mortality rate was 73.3% in patients >60 years of age and 50.2% in patients between 18 and 29.[7] Joseph *et al.* showed that survivors following a civilian brain gunshot are younger (28 ± 12 years) than the non-survivors (37 ± 23), although it was not statistically significant.[12] We believe that the younger age in our population is one of the causes of a higher survival rate than previously reported studies.

In our study, the majority of patients had mild (59.3%) PTBI followed by severe (33.9%) and moderate (6.8%) PTBI. Among patients with severe TBI, 70% had a missile-related injury and in 77.1% of patients with mild PTBI, non-missiles related injuries were the most frequent mechanism. Presenting GCS is influenced by the mechanism of injury and it consequently does affect the final outcomes.

The reported presenting GCS vary widely in the previous studies. Wu *et al*. compared the transbase versus transvault low-velocity PTBI and showed that the majority of patients with low-velocity of PTBI had mild GCS on hospital arrival (74.1%).[31] The opposite pattern was reported by Mansour *et al*. where the majority of patients with PTBI and subsequent vascular injuries had severe presenting GCS. In the mentioned study, almost all patients suffered from GSW (71 out of 72 patients).[17]

The previous studies address several prognostic factors affecting both survival rate and short-to-long-term functional outcomes.[1,3,11] Ambrosi *et al.* reported that preoperative GCS, pupil conditions, and intracerebral hematomas are prognostic factors among patients following GSW.[2] In Austria, Marhold *et al*. analyzed 27 patients with PTBI and concluded that initial GCS, trajectory, type of injury (low- or high-velocity), and pupil status are predictors of functional outcomes.[19]

We have shown that the majority of our patients suffered from a stab wound which is a low-velocity penetrating object. Globally reported, non-missile low-velocity PTBI is a very rare condition. The majority of studies are case reports or series in adult patients and the most frequent causes are occupational, assaults, or self-inflicted.[9,15,16,21,22,28,30,32]

The civilian PTBI however differs extensively regarding the epidemiology, the underlying mechanisms, and outcomes between nations. In the US where having gunshot is legal, the majority of assaults are caused by GSW leading to a high-velocity PTBI. In Iran, however, the use of or having a warm weapon is illegal. In contrast to studies from the United States or other regions of the world, the majority of our patients had non-missile and low-velocity stab wounds caused by assault or self-inflicted injuries. PTBI by low-velocity objects causes more localized injuries limited to lacerations or local bleeding along the wound tract. However, gunshots and shotguns are high-velocity (not as high as riffles or ballistic missiles) leading to blast effect and remote damage.[29]

Shotguns represent a distinct form of ballistic injury due to projectile scatter and variable penetration. Due in part to their rarity, existing literature on shotgun injuries is scarce.[25] In 2020, Schellenberg *et al.* investigated the epidemiology, injury patterns, and outcomes following shotgun-related PTBI using the National Trauma Data Bank. During 7 years, shotgun PTBI comprised 9% of all firearm injuries. Of included patients, the in-hospital mortality rate was 14% and the head was the most severely injured anatomical location. Unfortunately, this study did not categorize mortality rate by the anatomical locations.[26] Civilian-based shotgun head injuries are extremely rare in other parts of the world.[14] In our study, three out of 14 patients with shotgun PTBI have died.

Two of our patients suffering from low-velocity gunshot-related PTBI died in the hospital. The most frequently used weapon in our country is the handgun. Although injuries caused by handguns, hunting rifles, and other "high-velocity" objects have been well-described, events caused by "low-velocity" objects are particularly uncommon.[34] In our subgroups of shotgun and gunshot injuries, the mortality rate was very low. Therefore, another factor must be attributed as well.

The literature declares that the mortality rate among patients with PTBI is mostly related to missiles' trajectory. By reviewing 27 patients with low-velocity PTBI (stab), Wu *et al*. have shown that injuries through the skull base (transbase) increased the risk of injury to nerves and major vessels. although the patients with transvault injuries had lower functional outcome scores.[31] In 2003, Martins *et al*. showed that transventricular (or central type of bihemispheric) PTBI is significantly associated with a higher mortality rate.[20] DeCuypere *et al.* added deep nuclear and multi-lobar involvement to the transventricular injury as a predictor of dismal survival outcomes among pediatrics following intracranial gunshot injuries.[6] A systematic review of 1774 patients by Maragkos *et al.* has confirmed these patterns of injuries as the mortality predictors.[18] In our study, of five dead patients, three and two had injuries crossing the midline (biventricular) and coronal plane, respectively. Therefore, our high survival rate may be partially attributed to the trajectories of penetrating objects.

CONCLUSION

PTBI outcomes vary in different centers depending on mostly mechanism of injury. Its incidence and the subsequent mortality rate are relatively low in Iran, possibly due to the prohibition of possession or using warm weapons. Further, multicenter surveys with larger sample sizes are warranted to determine the association of on-admission and imaging characteristics, hospitalization course events, and the final clinical outcomes.

Limitations

Having no follow-up data on neurological deficits and chronic phase complication of the patients is regarded as the main limitation of the current study.

The small sample size is the main limitation of this study, which could have an adverse effect on meaningful comparisons between the subsets.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

Publication of this article was made possible by the James I. and Carolyn R. Ausman Educational Foundation.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Yousefi O, Azami P, Borazjani R, Niakan A, Yadollahi M, Khalili H. Civilian penetrating traumatic brain injury: A 5-year single-center experience. Surg Neurol Int 2023;14:28.