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Outcome of cranial firearm injuries in civilian population based on a novel classification system

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ABSTRACT

Background: Cranial firearm injuries (CFAIs) are expected to be frequent during warfare; however, it is becoming increasingly common among civilian population in our part of the world. These injuries are associated with significant morbidity and mortality in addition to financial loss. The objective of our study is to evaluate the pattern of gunshot injuries to cranium and their outcome.

Methods: The study was conducted on 114 patients presenting with CFAIs to Jinnah Postgraduate Medical Centre, Karachi, Pakistan, between June 2015 and January 2019. Patients were evaluated with respect to age, gender, pattern of injury, Glasgow coma scale on arrival, radiological and clinical assessment, surgical intervention, and Glasgow outcome score measured at 6 months follow-up.

Results: Among patients with cranial gunshot, injuries most were males (76.3%). More than 50% patients aged between 18 and 35 years. About 46.5% of patients presented with moderate traumatic brain injury commonly involving the temporal lobe (36.8%). Of total 114 patients, 84.2% were managed conservatively but wound debridement was done in all patients. At 6 months, the overall mortality in our patients was 33.3%. Patients with good outcome (GOS 4 and 5) were 30.7% and 35.9% patients had bad outcome (GOS 2 and 3). Complication rate was 14.9% and the most common complication was disseminated intravascular coagulation in 5.2%.

Conclusion: Surgical intervention has no significant benefit over conservative management on long-term mortality and should be limited to patients with large intracranial hematomas and intraventricular hematomas causing hydrocephalus.

Keywords: Ballistics, Civilian population, Firearm injuries, Glasgow outcome score, Jinnah classification

INTRODUCTION

Firearm injuries (FAIs) are rare causes of head trauma in civilians; however, its incidence is on the rise worldwide. Being part of the war against terrorism, cranial FAIs (CFAIs) have also increased over the past two decades in Pakistan. This increase is seen not only in the war zones or militarized areas but also in the civilian population. In mortality due to head trauma, the contribution of FAI is about 14% and the most common involved regions are head and neck.[6,19,28] Patients with CFAIs can have a wide range of presentation, like a single small puncture wound to large or multiple puncture wounds, from completely conscious level to altered level of consciousness with Glasgow coma scale (GCS) from 3 to 15, early or late presentation, associated extracranial FAIs including cervical injury or any major organ injury.

Damage caused by FAIs depends on the missile velocity. Large and distant tissue damage in the brain is usually caused by the missiles moving at high velocity usually >3000 ft/s. The extend of brain damage does not depend on the track of the missile only but also on the surrounding tissue damage caused by the shockwaves. On the other hand, lesser and limited damage is caused by the missiles moving at low velocity, mainly by direct crushing and laceration of the brain tissue.[4] There are multiple factors involved in the FAIs that can predict the degree of damage, such as size and speed of firearm, distance between source and target and site and angle of entry.[4,7,11,28] There are differences in the entry and exit wounds, typically an entry wound is small with internal beveling and exit wound is large with external beveling.[5,10,24-27]

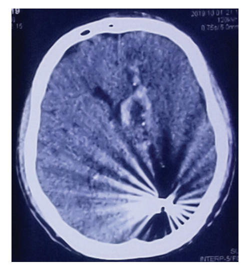
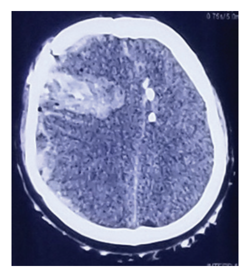
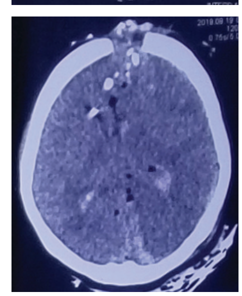
In general, bad prognostic factors for CFAIs are very low GCS score on admission or path of firearm crossing the midline or ventricles.[18] There is no classification in the literature to grade the severity and outcome of CFAIs and similarly no classification to indicate the need of surgery.[1] There is no consensus on management plan between different surgeons, some recommend for an early and aggressive surgical management but others advice for a conservative treatment option especially in cases where more than one lobe is involved or patient presents with a very low GCS.[12,13,23] There is high morbidity and mortality in CFAIs patients with bad prognostic factors and survivors usually need prolonged postdischarge care with rehabilitation.

MATERIALS AND METHODS

A total of 114 patients of all ages and gender with CFAIs admitted in the department of neurosurgery through emergency department, were enrolled in the study. All patients were followed prospectively from June 2015 to January 2019. Patients with CFAIs who were received dead at the neurosurgery department, patients with no penetration of cranial vault and with FAIs involving other parts of the body and patients who were lost to follow-up, were excluded from the study. Demographic and clinical data were obtained including age, gender, mechanism of firearm, severity of traumatic brain injury, site of brain involvement, type of treatment provided, complications, and outcome.

The patients with the CFAIs were categorized into three categories of traumatic brain injury severity according to the GCS; mild (GCS 13–15), moderate (GCS 9–12), and severe (GCS 3–8). The mechanism of firearm was categorized in suicidal, homicidal, and stray/accidental. Computed tomography (CT) scan was performed for all patients before admission and reviewed by two consultant neurosurgeons to identify their injury pattern. All patients were admitted in high dependency unit or intensive care unit. A need for a simple classification system to categorize these CFAIs was felt. To address that we would like to propose a CT scan based classification system for CFAIs (naming after our institute) to grade these injuries in reference to the areas of the brain involved as given in [Table 1]. The outcome based on different grades of this classification system.

Table 1: Jinnah cranial firearm injury classification.

Grade	Description	
I	Involvement of single lobe of brain.	
II	Involvement of two or more lobes of the brain.	
III	Crossing midline but not involving the ventricle.	
IV	Crossing the midline through the ventricles of the brain.	
V	Involvement of posterior fossa or brainstem.	

Management was divided into conservative and surgical treatment. Conservative treatment was comprised of wound debridement and medical treatment. Hematoma evacuation, placement of external ventricular drain, decompression with removal of missile, and bone fragments were taken as the surgical treatment. All patients who survived with neurological deficit were either discharged to home based nursing care or referred to rehabilitation centers. Follow-up at regular intervals for up to 6 months and outcome analysis was performed on Glasgow outcome score (GOS) at final follow-up. Frequency and types of secondary complication were also noted. SPSS version 23 was used for the statistical analysis. Means were calculated for all continuous variables whereas frequencies and percentages for all categorical variables. Chi-square test was used to assess the outcome with respect to the severity of head trauma, CFAIs grade, and type of management provided (surgical vs. conservative).

RESULTS

In our study, age of patients with CFAIs ranged from 6 years to 58 years but common age group affected was between 18 and 35 years of age [Table 2]. Mean age in this study was 28.1 ± 5.2 years and male gender was dominant 87 (76.3%) while 27 (23.7%) were females. Most of the patients were admitted with moderate brain injury, 46.4% while severe brain injury patients were 34.2%. A little over half the number of cases were homicidal (51.8%) cases but stray/accidental FAIs also contributed significant number of cases (33.3%). Involvement of the brain areas seen according to the CFAIs classification [Figure 1] based on CT scan showed single lobe involvement in 39% patients and involvement of two or more lobes was seen in 44.7%.

Most patients (84.2%) were managed conservatively but wound debridement was done in all of them. Good outcome was seen in 35(30.7%) patients with CFAIs and poor

Table 2: CFAIs demographic data.

Characters	*n* (%)	Survivors *n* (%)	Nonsurvivors *n* (%)	*P* value
Age				0.059
Below 18 years	21 (18.4)	16 (76.2)	5 (23.8)	
18–35 years	61 (53.5)	44 (72.1)	17 (27.8)	
Above 35 years	32 (28.1)	16 (50.0)	16 (50.0)	
Gender				0.413
Male	87 (76.3)	57 (65.5)	30 (34.4)	
Female	27 (23.7)	19 (70.4)	8 (29.6)	
GCS on admission				0.001
13–15	22 (19.3)	20 (90.9)	2 (9.1)	
9–12	53 (46.5)	38 (71.7)	15 (28.3)	
3–8	39 (34.2)	18 (46.1)	21 (53.8)	
Mechanism				0.291
Suicidal	17 (14.9)	11 (64.7)	6 (35.3)	
Homicidal	59 (51.8)	36 (61.0)	23 (38.9)	
Stray bullet/Accidental	38 (33.3)	29 (76.3)	9 (23.7)	
Grade				0.000
I	44 (38.6)	36 (47.3)	8 (18.2)	
II	37 (32.5)	29 (38.1)	8 (21.6)	
III	14 (12.3)	7 (50.0)	7 (50.0)	
V	12 (10.5)	3 (25.0)	9 (75.0)	
V	7 (6.1)	1 (14.2)	6 (85.7)	
Management				0.401
Conservative	96 (84.2)	63 (65.6)	33 (34.3)	
Surgical	18 (15.8)	13 (72.2)	5 (27.8)	
Complications				0.254
No complications	97 (85.1)	67 (69.1)	30 (30.9)	
DIC	7 (6.1)	3 (42.8)	4 (57.1)	
HCP	3 (2.6)	2 (66.7)	1 (33.3)	
CSF leak	2 (1.8)	1 (50)	1 (50)	
Wound infection	2 (1.8)	1 (50)	1 (50)	
Cerebritis/abscess	1 (0.9)	0 (0)	1 (100)	
Others	2 (1.8)	2 (100)	0 (0)	

CFAIs: Cranial firearm injuries, GCS: Glasgow coma scale, DIC: Disseminated intravascular coagulation, HCP: Hydrocephalus, CSF: Cerebrospinal fluid outcome (GOS 2–3) in 41 (36.0%) patients. A total of 38 (33.4%) patients brought with the CFAIs died, of which 31 patients died within the hospital during treatment and seven died after the discharge. Mean hospital stay was 9.12 days in our study. Total 17 patients developed complications, most common being the disseminated intravascular coagulation (DIC) in six (5.2%) followed by hydrocephalus (HCP) in four (3.5%) patients.

DISCUSSION

In neurosurgical practice, CFAIs are one of the less common causes of head injuries; however, it carries higher morbidity and mortality. Studies have shown that the common age group admitted with CFAIs is usually patients 20–35-year-old and male.[1,8,12,15] Our study also showed that predominantly young males of age 18–35 years were the victims of FAIs. Mean GCS on admission in one of the previously published studies was 8 ± 3.9[8] and 13.5 in another,[14] while it was 9 ± 3.5 in our study.

Social and cultural factors can be seen as we probe the mechanism of FAIs. The majority of FAIs were homicidal (51.8%) but stray/accidental FAIs also contributed a significant number of cases (33.3%). One formal study showed the similar pattern with 67.2% homicide cases.[21] About 12.2% of patients were brought after the suicidal FAIs, mainly young and middle age adults.

Initial investigation of choice for all the traumatic head injuries including FAIs, is CT scan and it is noted that its findings are correlated to prognosis.[9] CT scan can demonstrate multiple aspects of CFAI including trajectory and localization of the bullet; it also gives information regarding bone defect and bone pieces penetrating into the brain parenchyma causing damage [Figures 1-5]. Aarabi *et al*. have reported intraventricular bleeding (49%) as the most common pathologic lesion[1] while study by Cirak *et al*.[6] showed intracerebral hemorrhage as the most common finding (19%). In our study, the most common pathology was intracerebral hematoma (35%).

We observed that Grade I CFAIs (single lobe involvement) was the most common (39%) patients and temporal lobe was the most commonly involved lobe (36.8%). In contrast, one study showed the frontal lobe as the most frequently injured brain region (32.8%).[21] Management specially the surgical intervention is still a debatable topic. Surgical indications used by surgeons are large hematoma causing increased intracranial pressure, depressed or multiple fractures, or progressive neurological deficit.[31] Still many think that only the limited intervention is beneficial like the wound debridement.[32] We managed most of our patients conservatively which was limited to wound debridement 96 (84.2%) and used definite surgical intervention in only 18 (15.8%). Surgical indication in our patients was large intracerebral hematoma, accessible large bone or

Figure 1: Grade 1 - Involvement of single lobe of brain.

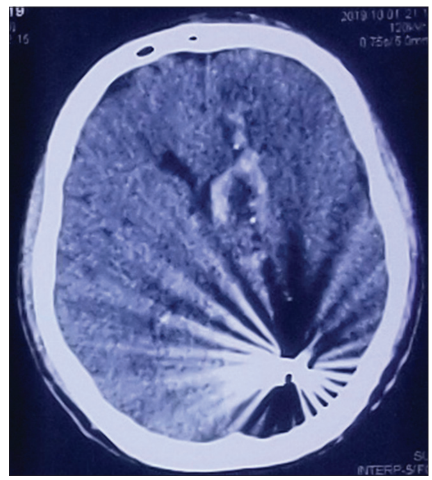


Figure 2: Grade 2 - Involvement of two or more lobes of the brain.

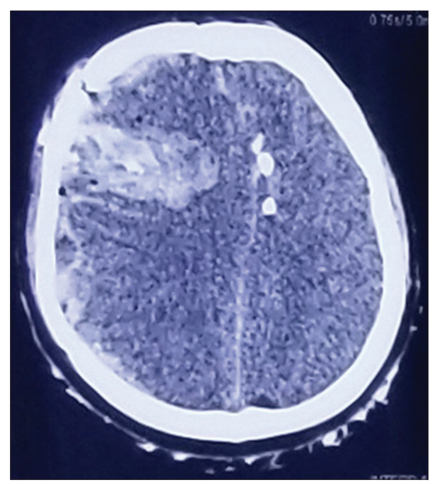


Figure 3: Grade 3 - Crossing mid-line but not involving the ventricle.

missile fragments in the parenchyma and intraventricular hemorrhage.

There is high variability seen among former studies regarding the mortality rates, one showing very low mortality rates of 7.7% while other having as high as 93% and many falling in between.[3,6,11,20,29] Another study showed mortality rate of 29.6%.[8] The overall mortality rate in all the patients was 33.3%. There was significant difference in the mortality rate according to the Jinnah CFAI classification [Table 3]. Highest mortality (85.7%) [Figure 5] was seen in patients with Grade V (posterior fossa/brain stem) injuries whereas Grade I FAIs had the lowest mortality (18.1%).

In our study, 17 (14.9%) patient developed complications. Among these patients, the most common complication was DIC in 5.2%, followed by HCP in 3.5% and cerebrospinal fluid leak in 1.8%. In comparison, one formal study showed paresis in 16.8% as the most common complication.[8]

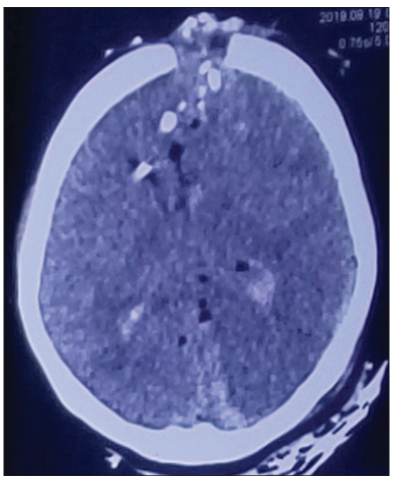


Figure 4: Grade 4 - Crossing the mid-line through the ventricles of the brain.

Figure 5: Grade 5 - Involvement of posterior fossa or brain-stem.

Formal studies show different results about the prognostic value of the age in CFAIs, with few showing that increasing age is a good prognostic factor while others showing the opposite results.[17,30] Our study showed that age of the patient is of prognostic value in outcome of CFAIs ($P < 0.05$). High mortality was seen with increasing age. There was no significant relationship found between mechanism of CFAIs and outcome in our study ($P > 0.05$) but one previous study showed more deaths in case of suicide.[21] Multiple studies showed that there is no benefit of surgical intervention for multilobar CFAIs and with low GCS especially below 5.[12,29] In our study, the severity of the traumatic brain injury was directly related to the outcome ($P < 0.05$). Highest mortality was seen in severe traumatic brain injury patients. There was no significant difference in outcome of both surgically managed and conservatively managed patients in our study ($P > 0.05$). The mortality rate in conservatively managed and surgically managed patients was, 34.3% and 27.7%, respectively.

Various studies have shown that poor prognosis was seen in CFAIs with interventricular hemorrhages and extent of brain injuries.[2,14,16] In our study, we found out that there is strong relation [Table 4] between the region of the brain involved in CFAIs and the outcome ($P < 0.05$). Grade I CFAI patients had higher recovery rates than other grades. Involvement of the ventricle or posterior fossa was important factors in prognosis of CFAI patients. Chances of survival in case of involvement of the ventricle and posterior fossa (Grade IV and V) were 21% while it was 75.7% in other grades combined (Grades I, II, and III). No patient in Grade V showed good recovery with 85.7% mortality.

Table 3: Mortality rate according to Jinnah CFAI classification.

Grade	Mortality rate (%)
Grade I	18.2
Grade II	21.6
Grade III	50
Grade IV	75
Grade V	85.7

CFAIs: Cranial firearm injuries

Table 4: Outcome according to Jinnah CFAI classification.

Grade	Outcome			Total	*P* value
	Good	Bad	Death		
Grade I	19	17	8	44	<0.001
Grade II	14	15	8	37	
Grade III	1	6	7	14	
Grade IV	1	2	9	12	
Grade V	0	1	6	7	
Total	35	41	38	114	

CFAIs: Cranial firearm injuries

CONCLUSION

FAIs are one of the fatal cranial injuries and need a specialized and prolonged in-hospital and posthospital medical care. Good GCS on admission, low CFAIs grade and selective surgical intervention are the important factors for a good outcome in these patients. Jinnah CFAI classification can be a simple way to classify the CT scan findings and predict the outcome but further work and validation is needed in the form of larger multi-centric studies.

Declaration of patient consent

Patient's consent not required as patients identity is not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

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