ORIGINAL ARTICLE

Outcomes and demostration of cranial firearm injuries: A multicenter retrospective study

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ABSTRACT

BACKGROUND: Cranial firearm injuries (CFAI) are associated with significant morbidity and mortality.This study was aimed to determine the factors affecting mortality of CFAI cases managed in our institution by a retrospective analysis of CT scans and clinical data.

METHODS: This multicenter retrospective study examined two hundred and nineteen patients presenting to neurosurgery clinics after CFAI between January 2012 and November 2014. Age, sex, Glasgow Coma Score (GCS), CT findings, and mortality and morbidity rates of the patients were analyzed to determine the factors affecting mortality.

RESULTS: Mean age of the study population was 24.19±12.25 years, 85.8% of them were male. The most common CT findings were fracture (100%), intracranial hemorrhage (61.2%), and an intracranially located foreign body (44.3%). A cranial operation was performed in 64.8% of the victims. Mean GCS on admission was 8±3.9, which increased in survivors ($p<0.05$).

CONCLUSION: CFAIs are associated with increased mortality and morbidity. We determined that many factors affected morbidity and mortality rates, and patient age, presence of intracranial hemorrhage, GCS, and treatment protocols were significantly associated with mortality.

Key words: Cranial firearm injuries; intracranial hemorrhage; morbidity; mortality.

INTRODUCTION

Firearm injuries (FAI) are common injuries with high mortality.[1,2] Head and neck regions are the most commonly injured areas in FAI, and 14% of all deaths due to head trauma are caused by FAIs.[3–5]

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FAIs are high-energy traumas.[5] The extent of cerebral parenchymal injury depends on the type of the firearm, the shooting range, and the angle of entry, mass, and velocity of the bullet.[5–7] While the majority of subjects exposed to FAI die at the scene, the mortality rate of those who can survive until hospital can be reduced by application of appropriate and aggressive efforts.[8,9]

No consensus has been reached yet regarding an appropriate CFAI classification and the indications for operation.[10] Some authors have recommended aggressive surgery and rapid treatment.[11–15] although some others have advocated a conservative treatment in the case of multilobular injury and a GCS less than 5.[15–17]

Our study explored age, sex, Glasgow Coma Score (GCS), CT findings, and mortality and morbidity rates in patients presenting to neurosurgery centers after CFAIs and analyzed the factors affecting mortality and morbidity.

MATERIALS AND METHODS

This multicenter study retrospectively evaluated patients who presented with CFAIs between January 2012 and November 2014, which included two hundred ans nineteen patients with penetrating intracranial injury. Age, sex, GCS score, CT findings, and mortality and morbidity rates were analyzed. The factors affecting mortality were analyzed. Mean age of the study population was 24.19±12.25 (range, 1–66) years and 85.8% of them were male. In 37.5% of the patients, the foreign body responsible for intracranial injury was located in the cranial cavity.

The study data were stored digitally and analyzed using SPSS (Statistical Package for Social Sciences) Version 16.0 software. The normality of distribution of the descriptive variables was tested with Kolmogorov Smirnov test. Logistic regression and Wilcoxon tests were used for the comparison of study data. The results were evaluated within a confidence interval of 95%, and a p value less than 0.05 was considered significant.

RESULTS

The findings of CT scans were assessed in all subjects. The scans revealed a fracture in a single bone in one hundred and twenty-three (56.2%) patients, intracranial hemorrhage (subarachnoid hemorrhage, lobar hemorrhage and hemorrhage along the trajectory) in one hundred and thirty-four (61.2%), intracranial foreign body in ninety-seven (44.3%), edema in thirty-six (16.4%), contusion outside the trajectory in fifteen (6.8%), pneumocephaly in seven (3.2%), and cerebrospinal fluid (CSF) fistula in five (2.3%) (Table 1).

Medical therapy was applied in 35.2% of the patients while an intracranial operation was performed in 64.8%. Duraplasty (54.8%) and decompression (46.1%) were the most commonly performed surgical operations (Table 2).

Mean GCS on admission was 8±3.9 in the overall study population. The mean GCS of the surviving patients was 14.6±1.3. GCS increased in one hundred and forty-two patients while it remained stable in thirteen ($p<0.05$).

Fifty-six (36.1%) of the survivors developed morbidity, of which paresis/plegia were the most common pathologies (n=26, 16.8%) (Table 3).

In patients with intracranial hemorrhage, mortality was higher among those who had ventricular hemorrhage or a hemorrhage along the trajectory. The patients having epidural hemorrhage, on the other hand, had a lower mortality ($p<0.05$) (Table 4).

Table 1. CT Findings of the patients

	n	%
Fracture type		
Single bone	129	58.9
Multiple bones		
Entry-Exit	51	23.2
Base fracture	39	17.8
Depression	17	7.7
Sinus fragmentation	2	.9
Total*	90	41.1
Hemorrhage type		
Intracerebral hematoma	78	35.6
SAH	39	17.8
Ventricular hemorrhage	27	12.3
Subdural hematoma	16	7.3
Epidural hematoma	12	5.5
Hemorrhage along the trajectory	7	3.2
Cerebellar hematoma	6	2.7
Total*	134	61.2
Foreign body*		
Shrapnel	68	31.1
Bone fragment	23	10.5
Undefined foreign body	10	4.6
Bullet	4	1.8
Total*	97	44.3
Edema	36	16.4
Contusion	15	6.8
Pneumocephaly	7	3.2
CSF fistula	5	2.3

*There are inconsistencies between the number of the individual cells and the total numbers due to the presence of more than a lesion in a given patient.

Table 2. Treatment approaches in FAIs

	n	%
Medical therapy	77	35.2
Surgical therapy		
Duraplasty	120	54.8
Decompression	101	46.1
Craniotomy	53	24.2
Hematoma drainage	12	5.5
Shrapnel removal	5	2.3
Craniectomy	4	1.8
Total*	142	64.8

*There are inconsistencies between the number of the individual cells and the total numbers due to the presence of more than a lesion in a given patient.

Table 3. The pathologies responsible for patient morbidity

	n	%
Paresis/plegia	26	16.8
Optic nerve injury	19	12.3
Dysphasia	8	5.2
Facial nerve injury	2	1.3
6. nerve injury	2	1.3
No auditory functions	1	0.6
Vegetative form	1	0.6
Total*	56	36.1

*There are inconsistencies between the number of the individual cells and the total numbers due to the presence of more than a lesion in a given patient.

While the mortality of single bone injury, depression fractures, and base fractures was lower, it was higher for lesions with entry and exit points (p<0.05) (Table 5).

Sixty-four (29.2%) FAI victims died. Considering the factors causing mortality, mortality rates in patients with a lower GCS on admission, multiple fractures, hemorrhage, edema, and undergoing medical treatment were higher (p<0.05) (Table 6).

DISCUSSION

Firearm injuries are very important pathologies for neurosurgery practice due to their higher mortality and morbidity rates as well as the potential for improved patient outcomes with timely and appropriate surgical interventions.[1,2,8] As a result of escalating tension and civil wars in various regions of the Middle East beginning in 2010, a significant rise in terror incidents has been witnessed, leading to both an increased number and severity of FAI cases admitted to hospitals in our country.[3,16]

Previous studies have reported that the patients admitted for FAI were usually 20–35 years old and predominantly male.[4,8,10,16,18] In agreement with the literature, our study found that predominantly young males were the victims of FAIs.

Computed tomography should be ordered as an initial step in FAIs, and it is noted that lesions on tomography are correlated to prognosis.[19] CT allows evaluation of bullet position and localization in cranium; it also provides information regarding the status of bone structures and brain parenchyma. The extent of tissue injury inflicted by FAIs depends on many factors, of which foreign body's velocity is the most important one.[5–7] Depending on these factors, a foreign body may remain in the scalp or it may tear dura and injure intracranial structures.

Table 4. The effect of hemorrhage type on mortality

	Mortality				p
	Survived		Died		
	n	%	n	%	
Ventricular hemorrhage	8	5.2	19	29.7	<0.001
Intracerebral hematoma	51	32.9	27	42.2	0.192
Hemorrhage along the trajectory	1	0.6	6	9.4	0.001
Cerebellar hematoma	5	3.2	1	1.6	0.493
SAH	23	14.9	16	25.0	0.077
Epidural	35	22.6	4	6.3	0.004
Subdural	10	6.5	6	9.4	0.458

Table 5. The relationship between the bone structure and mortality

	Mortality				p
	Survived		Died		
	n	%	n	%	
Single bone	88	56.8	25	29.1	0.017
Entry-Exit	23	14.8	28	43.8	<0.001
Depression	16	10.3	1	1.6	0.028
Base	35	22.6	4	6.3	0.004

Table 6. Factors causing mortality

	B	S.E.	Wald	Df	Sig.	Exp(B)
Age	-0.047	0.023	4.258	1	0.039	.954
Sex	1.467	0.857	2.930	1	0.087	4.335
GCS	-1.083	0.206	27.642	1	0.000	.339
Hemorrhage	1.982	0.701	7.981	1	0.005	7.255
Bone fracture	1.100	0.576	3.654	1	0.056	3.005
CSF fistula	-16.539	14494.254	0.000	1	0.999	.000
Foreign body	0.146	0.565	0.067	1	0.796	1.157
Edema	-0.887	0.846	1.100	1	0.294	.412
Contusion	1.379	1.304	1.118	1	0.290	3.970
Pneumocephaly	-1.053	1.819	0.336	1	0.562	.349
Treatment modality	-1.199	0.335	12.795	1	0.000	.302
Constant	4.934	1.822	7.337	1	0.007	138.953

[10,11,17,20] Carey et al. and Kirkpatrick et al. have reported that mortality is related to the affected region, secondary injuries, and lesions of brain stem.[13,21] Martins et al. have reported that 17% of bullets did not penetrate dura; the authors attributed this finding primarily to lower shooting velocities of non-military firearms.[4] Bone fragments and bullets cause direct injury on tissue although they also lead to injury of distant brain tissues via short time shockwaves.[5] Aarabi et al. have reported that the most common pathologic lesion is intraventricular bleeding (49%)[22] while Çırak et al. most commonly observed intracerebral hemorrhage (19%). Various studies have reported a SAH rate of 31–80%.[23–26] In our study, no fracture was observed in 8% of patients, a lower figure than that reported by Martins et al., probably because of the use of military firearms in this region. In this study, intracerebral hemorrhage was the most common type of hemorrhage since brain tissue occupies the largest space within the intracranial cavity. We believe that the rate of shrapnel injuries was high owing to the mine injuries during crossing the borders illegally and the use of cluster bombs to damage as many people as possible during armed conflicts. We also suggest that parenchymal injury may have been worsened by high-energy shrapnel impacts causing cranial bone fragmentation with fragments penetrating cranial cavity.

We suggest that the mortality rate may have been increased by intracranial pressure alterations due to hemorrhages opening into ventricular cavity, augmented brain tissue injury along the bullet trajectory, and injury to important neural tissues. We also think that serious parenchymal injury caused by entry and exit lesions that crossed the midline may have boosted mortality rates. To our opinion, the mortality rate associated with epidural hemorrhage was lower since these lesions were easily decompressed and did not cause any parenchymal injury.

Discussions concerning emergency procedures applied for FAIs exist. The indications for surgical intervention include open depression or multiple fractures, CSF fistula, active hemorrhage, progressive neurological deficit, and increased intracranial pressure.[19] Some authors have advocated a less aggressive cleaning procedure preserving as much brain tissue as possible[27,28] while some others have suggested a more aggressive approach consisting of debridement of necrotic tissue, hematoma evacuation, removal of bone fragments and foreign material as much as possible, establishing hemostasis, and dural closure.[11–15,29–32] Surgical intervention is not recommended for multilobular injuries and a GCS below 5 owing to lack of survival benefit.[15,32] Grahm et al. do not recommend surgery in the absence of any significant hematoma or a bihemispheric or multilobar injury, or when GCS is above 6–8.[30] Çırak et al.,[19] Ziyal et al.,[9] and Stone et al.[32] have operated 86%, 35%, and 31% of their patients, respectively, most commonly with duraplasty. Our rate of surgical intervention was higher than many former studies, primarily owing to a better clinical condition and a higher GCS in our patients. We believe that duraplasty application is common since firm dural closure is a component of all intracranial operations although a few exceptions exist.

Patients may develop hemiparesis, cranial nerve palsy, and seizure after FAI.[34] Ziyal et al. have reported a morbidity rate of 47%, with mono/hemiparesis being the most common morbidities.[9] Former studies have suggested that morbidity rate increases when hemorrhage developes near the ventricle.[4,35] The morbidity rate in our study was 36.1%, with visual loss being the most common pathology. To our opinion, the morbidity rate is dependent on lesion site and the applied treatment. Furthermore, in our study, the likelihood of optic nerve injury may have been higher owing to a higher rate of complex fractures while a lower morbidity rate may have stemmed from a lower rate of hemorrhages opening into the ventricle.

Studies from different centers have reported mortality rates ranging between 7.7% and 93%[4,12,15,17,18,30,32] while our mortality rate was 29.6%. The mortality rates have possibly been affected by equipment, expertise, and treatment protocols at the treating centers.

There is no consensus concerning the prognostic importance of age in FAIs involving the head. Some authors have reported a lower mortality with increasing age,[37] whereas some others have demonstrated otherwise.[12,17,38] We detected an inverse correlation between age and mortality. The likely reason of this observation may be the relatively young age of the victims who engaged in armed conflicts and the increased lethality of firearms used in such conflicts.

GCS determines the treatment planning and long-term outcomes of the patient.[5] Çırak et al.[19] have reported that a patient's prognosis can be predicted on the basis of CT findings and GCS. Aarabi et al.[22] and Hoppe et al.[39] have reported mean admission GCSs of 7.8 and 13.5, respectively. They noted that GCS was inversely proportional to prognosis. Aldrich et al. have reported that GCS usually improves following resuscitation.[23] Kim et al. have reported an adequate improvement in all but one patient with GCS >8 whereas those having GCS<8 has had increased mortality and morbidity.[35] Former studies have reported that GCS was inversely proportional to mortality.[4,10,12,16,18,30,3335,36] Complying with the literature data, an inverse relationship between GCS and mortality was also detected.

It has been reported that there is a linear relationship between the extent of brain injury and mortality and morbidity rates.[3,10] Williams et al, and Raul et al. have reported that the ballistic trajectory and the extent of injury affect the rates of morbidity and mortality.[40,41] Various studies have particularly stressed that intraventricular hemorrhages are associated with poor prognosis.[13,35] Gressot et al. have reported that patients having a hematoma had a higher mortality rate.[18] In our study, the presence of hemorrhage was an important predictor of mortality. Hemorrhage leads to deranged tissue integrity, impaired local circulation, and ischemia; it is therefore a predictor of brain damage and death.

In patients with intracerebral hematoma, clinical status is determined by the location of hematoma and its rate of accumulation.[5] In patients hospitalized with FAI, favorable outcomes can be obtained by appropriate interventions performed before irreversible changes develop.[10] Some authors do not recommend surgery for patients with very low GCS.[15,16,30,37] Hence, the higher mortality in medically managed patients in our study may have resulted from avoiding surgery in patients with a GCS of 3.

Firearm injuries are associated with significant morbidity and mortality. It was determined in this study that many factors affected morbidity and mortality rates, and the mortality rate was particularly affected by patient age, presence of hemorrhage, GCS, and treatment protocols applied.

Conflict of interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZET*

Kraniyal ateşli silah yaralanmalarının dağılımı ve sonuçları: Çok merkezli geriye dönük çalışma

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AMAÇ: Kraniyal ateşli silah yaralanmaları (KASY) sonucu hastanemizde tedavi edilen olgular, bilgisayarlı tomografi (BT) sonucu ve klinik verilerine göre incelendi, mortalite üzerine etkili faktörleri belirlemek için veriler geriye dönük olarak değerlendirildi.
GEREÇ VE YÖNTEM: Çok merkezli çalışmamızda beyin cerrahisi kliniklerine KASY sebebi ile Ocak 2012–Kasım 2014 tarihleri arasında başvuran 219 hasta geriye dönük olarak değerlendirildi. Hastaların yaş, cinsiyet, Glascow Coma Skala (GKS) skoru, BT bulguları, morbidite ve mortalite durumları incelendi. Mortaliye etki eden faktörler analiz edildi.
BULGULAR: Hastaların yaş ortalaması 24.19±12.25 yıl olup, %85.8'i erkekti. Bilgisayarlı tomografide belirlenen en sık bulgular kırık (%100), intrakraniyal kanama (%61.2) ve intrakraniyal yabancı cisimdi (%44.3). Hastaların %64.8'ine intrakraniyal operasyon uygulandı. Hastane başvurusu esnasında ortalama GKS puanı 8±3.9, yaşayan hastaların ortalama GKS puanının arttığı saptandı ($p<0.005$). Hastaların mortalite oranı %29.2 ve morbidite oranı %36.1 idi. Mortaliteye etki eden faktörlerin GKS, kırık tipi, kanama, ödem ve tedavi şekliydi ($p<0.05$).
TARTIŞMA: Ateşli silah yaralanmaları morbiditesi ve mortalitesi yüksek yaralanmalardır. Morbidite ve mortalite üzerine birçok faktörün etki ettiği ve özellikle mortalite üzerine hastanın yaşı, kanamanın varlığı, GKS ve tedavi protokollerinin etki ettiğini saptadık.
Anahtar sözcükler: Kraniyal ateşli silah yaralanmaları; intrakraniyal kanama; morbidite; mortalite.

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