Editorial Office UTD (dergi@travma.org)
Kime: Ali Erdem Yildirim (alierdemyildirim@gmail.com)
Bilgi: dergi@travma.org
Konu: Your article is accepted for publication (UTD-84883)

### Ref: UTD-84883Baslik: Kraniyal Atesli Silah Yaralanmalarinin Dagilimi ve Sonuclari: Cok Merkezli Retrospektif Calisma - Outcomes and Demostration of Cranial Firearm Injuries: A Multicenter Retrospective StudyDear. Dr. Ali Erdem YildirimThe article that you have submitted to the Ulusal Travma ve Acil Cerrahi Dergisi (Turkish Journal of Trauma & Emergency Surgery) entitled 'Kraniyal Atesli Silah Yaralanmalarinin Dagilimi ve Sonuclari: Cok Merkezli Retrospektif Calisma - Outcomes and Demostration of Cranial Firearm Injuries: A Multicenter Retrospective Study' has been accepted for publication following peer review. We wish you success and hope to communicate with you again. Recep Guloglu, MDEditor for the Turkish Journal of Trauma and Emergency Surgery

### Outcomes and Demostration of Cranial Firearm Injuries: A Multicenter Retrospective Study

Kadir Cınar1, Mehmet Secer2, Fatih Alagoz3, Murat Ulutas4, Ozhan Merzuk Uckun3,

Ali Erdem Yıldırım3, Ahmet Gurhan Gurcay5,Yahya Guvenc6, Haydar Celik7, Fırat Narin8

1Department Of Neurosurgery Şehitkamil State Hospital,gaziantep
2Department Of Neurosurgery Deva Hospital,gaziantep
3Department Of Neurosurgery Ankara Numune Education And Research Hospital,ankara
4Department Of Neurosurgery Sanko University Konukoglu Hospital,gaziantep
5Department Of Neurosurgery Ankara Ataturk Education And Research Hospital, Ankara
6Dr.n.k. Sincan State Hospital, Neurosurgery, Ankara
7Department Of Neurosurgery, Ankara Training And Research Hospital, Ankara
8Department Of Neurosurgery, Ankara Memorial Hospital,Ankara

**Abstract**

Cranial firearm injuries (CFAI) are associated with significant morbidity and mortality.

***Objective:***To determine the factors affecting mortality of CFAI cases managed at our institution by a retrospective analysis of CT scans and clinical data.

**Materials and Method:** This multicenter retrospective study examined 219 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:** The mean age of the study population was 24.19±12.25 years, 85.8% of them are 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. The mean GCS on admission was 8±3.9 and it increased in survivors (p<0.005). The mortality and morbidity rates were 29.2% and 36.1%, respectively. GCS, fracture type, hemorrhage, edema, and the mode of treatment were the factors causing mortality (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 and mortality.

**ÖZET**

 Kranial ateşli silah yaralanmaları (KASY), mortalite ve morbiditesi yüksek yaralanmalardır.

***Amaç:***KASY sonucu hastanemizde tedavi edilen vakaların CT sonucu ve klinik verilerine göre inceleyerek, mortalite üzerine etkili faktörleri belirlemek için veriler retrospektif olarak değerlendirildi.

**Materyal ve Metod:** Çok merkezli çalışmamızdaBeyin cerrahisi kliniklerine KASY sebebi ile Ocak 2012- Kasım 2014 tarihleri arasında başvuran 219 hasta retrospektif olarak değerlendirildi. Hastaların yaş, cinsiyet, Glascow Coma Skala (GKS) skoru, CT 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. CT’de belirlenen en sık bulgular fraktür (%100), intrakranial kanama (%61.2) ve intrakranial yabancı cisim (%44.3) saptandı. Hastaların % 64.8’sine intrakranial 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, fraktür tipi, kanama, ödem ve tedavi şekliydi (p<0.05).

**Sonuç**: ASY morbiditesi ve mortalitesi yüksek yaralanmalardır. Morbidite ve mortalite üzerine bir çok faktörün etki ettiği ve özellikle mortalite üzerine hastanın yaşı, kanamanın varlığı, GKS ve tedavi protokollerinin etki ettiğini saptadık.

**Anahtar Kelimeler:**Kranial ateşli silah yaralanmaları, intrakranial kanama, mortalite ve morbidite

**INTRODUCTION**

Firearm injuries (FAI) are common injuries with a high mortality [1,2]. Head and neck regions are the most commonly injured areas in FAIs and 14% of all deaths due to head trauma are caused by FAIs [3,4,5].

FAIs are high-energy traumas [5]. The extent of cerebral parenchymal injury depends on the type of firearm, the shooting range, and the angle of entry, mass, and velocity of bullet [5,6,7]. 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 [11,12,13,14,15], although some others have advocated a conservative treatment in the case of multilobular injury and a GCS less than 5 [15,16,17] .

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 METHOD**

This multicenter study retrospectively evaluated patients who presented with CFAIs between January 2012 and November 2014. It included 219 patients with penetrating intracranial injury. Age, sex, GCS score, CT findings, and mortality and morbidity rates were analyzed. The factors affecting mortality were analyzed. The mean age of the study population was 24.19±12.25 (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 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 123 (56.2%) patients, intracranial hemorrhage (subarachnoid hemorrhage, lobar hemorrhage and hemorrhage along the trajectory) in 134 (61.2%), intracranial foreign body in 97 (44.3%), edema in 36 (16.4%), contusion outside the trajectory in 15 (6.8%), pneumocephaly in 7 (3.2%), and cerebrospinal fluid (CSF) fistula in 5 (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).

The 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 142 patients while it remained stable in 13 patients (p<0.05).

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

 In the patients with intracranial hemorrhage the 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)

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 admitting 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 [5,6,7]. Depending on these factors, a foreign body may remain in the scalp or it may tear dura and injure intracranial structures [10,11,17,20] . Carey et al. and Kirkpatrick et al. reported that mortality was related to the affected region, secondary injuries, and lesions of brain stem [13,21]. Martins et al. 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 a direct injury on tissue, although they also lead to injury of distant brain tissues via short time shockwaves [5]. Aarabi et al. reported that the most common pathologic lesion was intraventricular bleeding (49%) [22] while Çırak et al. most commonly observed intracerebral hemorrhage (19%). Various studies have reported a SAH rate of 31-80% [23,24,25,26]. 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 are easily decompressed and do 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 [11,12,13,14,15,29,30,31,32]. Surgical intervention is not recommended for multilobular injuries and a GCS below 5 owing to lack of survival benefit [15,32]. Grahm et al. did 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] 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 was 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. reported a morbidity rate of 47%, with mono/hemiparesis being the most common morbidities [9]. Former studies have suggested that morbidity rate increased when hemorrhage developed 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 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 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 patient [5]. Çırak et al. [19] 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] reported mean admission GCSs of 7.8 and 13.5, respectively. They noted that GCS was inversely proportional to prognosis. Aldrich et al. reported that GCS usually improved following resuscitation [23]. Kim et al. reported an adequate improvement in all but one patient with GCS>8 whereas those having GCS<8 had increased mortality and morbidity [35]. Former studies have reported that GCS was inversely proportional to mortality [4,10,12,16,18,30,35,36]. Complying with the literature data, we also detected an inverse relationship between GCS and mortality.

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. reported that the ballistic trajectory and the extent of injury affected the rates of morbidity and mortality [40,41]. Various studies have particularly stressed that intraventricular hemorrhages were associated with poor prognosis [13,35]. Gressot et al. 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 the 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 did not recommended 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.

In conclusion, firearm injuries are associated with significant morbidity and mortality. We determined 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.

**Table Lagends**

**Table 1:** CT Findings of patiens

**Table 2:**Treatment approaches in FAIs

**Table 3:** The pathologies responsible for patient morbidity

**Table 4:** The effect of hemorrhage type on mortality

**Table 5:** The relationship between the bone structure and mortality

**Table 6:** Factors causing mortality

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Table 1. CT Findings

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | 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

Table 4. The effect of hemorrhage type on mortality

|  | Mortality | P |
| --- | --- | --- |
| Survived | Died |
| 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 |
| 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 |