Craniocerebral Gunshot Wounds: Analysis of 288 Cases, A Clinical Review

Kranioserebral Ateşli Silah Yaralanması: 288 Olgunun İncelenmesi

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Abstract: This paper is a retrospective analysis of 288 craniocerebral gunshot wounds treated over a 5-year period. Twenty-one in-hospital deaths occurred, most as a direct result of brain injury. The level of central nervous system (CNS) damage was the most valuable prognostic factor in these cases. The presence of diffuse brain damage, brainstem injury, CNS infection, or ventricular injury was associated with poor outcome.

Key Words: Craniocerebral injury, prognostic factor, gunshot wound

Özet: Bu çalışmada 5 yıllık bir peryotta kranioserebral ateşli silah yaralanması nedeniyle tedavi edilen 288 vakanın retrospektif analizi sunuldu. 21 hasta hastahanede öldü. Ölümlerin çoğu beyin hasarının direk etkisi sonucu oldu. Santral sinir sistemi (SSS) hasarının düzeyi en önemli prognostik faktördür. Diffüz beyin hasarı, beyin sapı zedelenmesi, SSS enfeksiyonu, veya ventriküler zedelenmenin varlığı kötü prognozu işaret eder.

Anahtar Kelimeler: Kranioserebral yaralanma, prognostik faktör, ateşli silah yaralanması

INTRODUCTION

Craniocerebral gunshot wounds are associated with a high mortality rate (4,6,21,22,23,25), and mortality after surgery is approximately 20% (6,9,10). These wounds may affect only the scalp but depending on bullet speed and the distance between firearm and target, they can also damage the cranium and intracranial structures. Mortality and morbidity associated with craniocerebral missile wounds are affected by many factors, including patient transport, antibiotic therapy, surgical techniques, and follow-up procedures (3,7,11,16,17,33). In recent years, there has been a drop in mortality associated with penetrating head wounds. For combat casualties of the Vietnam War, resuscitation in the field by paramedical personnel, rapid transport by helicopter to the specially equipped medical facilities, adequate supply of whole blood, and the higher level of care supplied by these facilities all contributed to an improved survival rate (19,29). In the cases of Vietnam war, the neurosurgical postoperative mortality rate was 8% to 10% (9,16).

In general, it appears that the most important prognostic factors are the Glasgow Coma Scale (GCS) score at the time of initial assessment, and elements directly related to the wound, such as the presence of ventricular injury or bihemispheric injury (11). Here we report the results of a retrospective study of 288 craniocerebral gunshot wounds treated over a 5-year period. These data are used as a basis for a review and discussion of the literature concerning management and complications of high-velocity craniocerebral gunshot wounds.

MATERIALS and METHODS

The authors treated 288 patients with craniocerebral gunshot wounds, between November 1992 and November 1997 at GATA Medical School, Diyarbakir and at the Van Military Hospital. All the patients were males, and their mean age was 22 years (range, 4 to 45 years). Individuals who were dead on arrival, or who had gunshot wounds of the scalp that did not penetrate the cranium, were excluded from the study.

The patients were initially evaluated by paramedics, and, following more immediate life-saving procedures, were transferred by helicopter ambulance to the facility where neurosurgical management was then carried out. There has been a mean period of 2 hours elapsed between injury and arrival at hospital. All patients had preoperative x-rays of the skull, and 35 patients in stable condition underwent computed tomography (CT) scans (Figures 1-2). All individuals underwent surgery, and any intracranial bone and metal fragments that were visible and palpable in the preoperative period were removed during the first operation. Necrotic cerebral tissue was debrided. Bone and metal fragments in deep or intraventricular locations were left in place. The primary closure was performed for the dural defects in 45 cases (15.7%). The dura was closed with pericranium or temporal muscle fascia in 220 cases (76.4%), with a tensor fascia lata graft in 17 cases (5.9%), and with a cadaver dura graft in 6 cases (2.1%). According to our experience, the primary closure or the duraplasty should be performed for the dural defects in the patients with brain edema. All patients received third-generation cephalosporins for 14 days postoperatively. In addition, they followed standard medication protocols including diuretics, anticonvulsants, and analgesics. We used the anticonvulsant phenytoin, since it can be administered intravenously in doses of 300-600 mg/day for adults and 4-7 mg/kg/day for pediatric patients. Thirteen patients (4.5%) whose CT scans showed extensive brain edema were intubated and connected to mechanical ventilators. We monitored their intracranial pressure (ICP) closely, and they were given diuretic therapy as required. Only 10 cases required ICP monitoring, and these patients' GCS scores ranged between 4 and 8. Postoperatively, all patients were followed up with CT scans. In 77 cases, bone and metal fragments were lodged in deep locations, and these individuals were treated conservatively. They underwent surgery only after neurological dysfunction occurred.

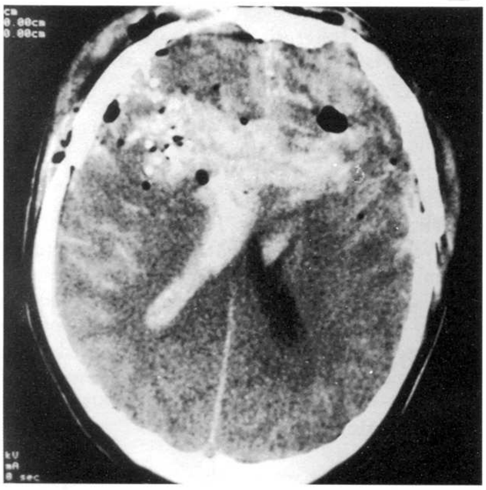

Figure 1: Computed tomography scan demonstrating diffuse brain injury, intracerebral-intravantricular hemorrhage, and retained bone fragments.

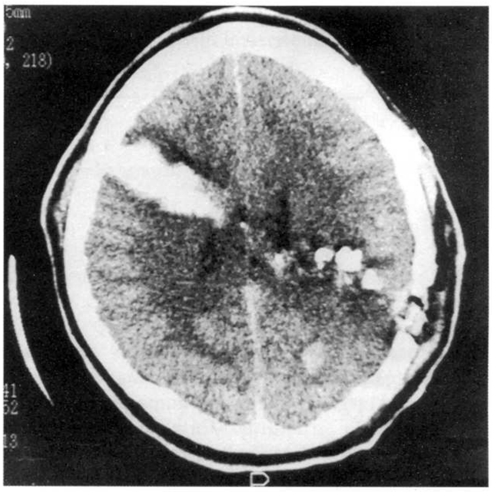

Figure 2: Computed tomography scan showing a bullet trajectory through the ventricles, as well as blood collection and retained bone fragments.

RESULTS

The physical materials responsible for the craniocerebral injuries in our 288 patients are listed in Table I. Shrapnel fragments were most common (65%), with bullets ranked second (35%). These objects caused certain pathological changes, specifically in the brain, CNS, and other vital structures. Many of the resultant lesions ultimately led to death, and these are listed and ranked in Table II. Diffuse brain injury caused the most deaths, accounting for 10 (47.1%) fatalities in our patient group. We also identified the sites of cranial penetration, and these are shown in Table III. According to our study, the most frequently injured brain field was the frontal lobe (26%), but the parietal and the temporal lobes can also be affected by these wounds. Twenty-one patients in our series died, making the mortality rate 7.3%. The relationship between the mortality and the preoperative GCS score is summarized in Table IV.

The patients were followed for a mean of 2 years (range, 3 months to 3 years). All underwent long-term hospitalization of 6 months after being transported and, prolonged postoperative rehabilitation was performed during this period. Complications after their surgery also dictated outcome for patients. The complications encountered, and their effects on mortality are shown in Table V.

Table I: Materials that caused penetrating craniocerebral wounds in our patients.

Material	Cases N (%)	Deaths N (%)
Bullet	101 (35)	12 (11.9)
Shrapnel	187 (65)	9 (4.8)
Total	288 (100)	21 (7.3)

Table II: Causes of death in our patients with craniocerebral wounds.

Cause of Death	Cases N (%)
Diffuse brain damage	10 (47.6)
Brainstem injury	4 (19.1)
Intracranial infection	3 (14.3)
Systemic infection	2 (9.5)
Pulmonary embolism	2 (9.5)
Total	21 (100)

Table III: Sites of cranial penetration and material involved.

Site	Bullet	Shrapnel	Total	%
Frontal	30	45	75	26.0
Temporal	14	21	35	212
Parietal	17	35	52	18.1
Occipital	5	22	27	9.4
Frontotemporal	5	7	12	4.2
Temporoparietal	7	9	16	5.5
Frontoparietal	10	14	24	8.3
Parietooccipital	3	9	12	4.2
Bifrontal	3	4	7	2.4
Vertex	-	4	4	1.4
Orbitocranial	3	5	8	2.8
Posterior fossa	2	5	7	2.4
Multiple sites	2	7	9	3.1
Total	101	187	288	100

Table IV: The relationship between mortality and patients' initial assessment Glasgow Coma Scale (GCS) score.

GCS Score	Cases (N)	Deaths (N) Rate	Mortality
15-14	20	0	0
13-11	90	2	2.2
10-8	109	4	3.6
7-5	65	12	18
<5	4	3	75.0

Table V: Postoperative complications associated with penetrating craniocerebral injuries in our patients.

Complication	Cases (N)		%	
Retained deep intracranial	77		26.7	
bone or metal fragment				
Epidural hematoma	1		0.3	
Subdural hematoma	1		0.3	
Intracerebral hematoma	3		1.0	
CSF fistula	13		4.5	
Intracranial infection	Wich CSF	Without CSF	%	%
	filtula	filtula		
Purulent ventriculitis	1	-	0.3	-
Cerebral abscess	3	2	3.8	0.6
Subdural empyema	2	-	0.6	-
Meningitis	2	-	0.6	-
Superficial infection	1	-	0.3	-

Of the 267 patients who survived their injury, 195 achieved a sufficient level of self-care such that they could be discharged. Seventy-two patients failed to recover well, and required continued care in a medical facility. These patients started rehabilitation therapy as soon as they were stable. Rehabilitation is a creative, cooperative effort by the health care team, the patient, and the family, which is aimed at optimizing mental, social, and vocational aptitudes. Patient scores on the Glasgow Outcome Scale (GOS) are listed in Table VI.

Table VI: Patient Glasgow Outcome Scale (GOS) scores.

GOS Score	Cases (N)
Good recovery (5)	101
Moderate disability (disabled but independent) (4)	144
Severe disability (conscious but disabled) (3)	20
Persistent vegetative state (2)	2
Death (1)	21

DISCUSSION

The energy contained in a penetrating object can be classified as low, medium, or high. Missiles of high velocity, such as bullets from military and hunting rifles, cause extensive damage to tissues in the path of the projectile. High-velocity injuries also cause secondary damage due to fragmentation of bone, which is shattered by the missile on impact. This secondary damage can be more serious than that caused by the bullet itself (11).

Cervical spine, plain skull x-rays, and brain CT scans should be obtained once the patient is stabilized. In this way, associated hematomas, the presence or absence of intraventricular missile fragments, midline shifts, hydrocephalus, obliterated basal cisterns, the missile trajectory, lacerations, and the length and location of in-driven bone fragments may be determined (13). Cervical and skull plain X-rays were obtained for all of our patients, but brain CT scans were done on only 35 patients who were deemed stable on admission. As a result, 77 patients had small bone and metal fragments that could not be detected grossly during surgery, and these pieces were left untouched. Many military neurosurgeons advocate finger palpation of the incision for bone fragments, but, since small fragments may be missed using this method, it is not recommended (16). The use of intraoperative ultrasonography is a safer and more sensitive way to localize bone and missile fragments, and other in-driven foreign bodies (14). For our cases, this type of imaging was not available.

Brain CT scans were done on all patients in the postoperative period, and infection was detected in only two individuals who had retained bone fragments. These patients underwent further surgery. We encountered no complications of bone or metal fragment migration, and noted no neurological deficits in these two infected individuals.

Level of consciousness is a reliable indicator of severity of injury, and correlates predictably with morbidity and mortality (10,25,30). Table IV shows the GCS score as a predictor of fatality. Looking at patient GCS scores on initial examination, those scoring 15-13 had a mortality rate of 0%. This rate increased significantly, to 5.5%, for those scoring 13-8. Further analysis of coma patients revealed that individuals with GCS scores of 8-4 had a mortality rate of 18.7%. If the score was below 4, the rate was 75%.

Mortality is high in individuals with missile injury to the posterior fossa. In the Israeli-Lebanese conflict, the mortality rate for posterior fossa lesions was 89% (7). Of our seven patients who suffered wounds of the posterior fossa, four (57.1%) died as a result of brainstem injury. High mortality rates are associated with high velocity missiles and involvement of the midline structures, such as the vermis and the pontomedullary region (16,18,20,31).

We found that ventricular injury was also a predictor of poor outcome. In cases involving penetrating craniocerebral gunshot wounds, the tracts through the ventricles made by foreign bodies (bullets, shrapnel) can cause injury, leaving a significant collection of intraventricular blood. Such damage is associated with a particularly poor prognosis. Contrast enhancement of intraventricular ependymal tissue, or the accumulation of intraventricular contrast material indicates serious ventricular injury (5). Our findings were consistent with earlier reports that gunshot wound patients with ventricular injuries have the highest mortality rates (12,28). In our patient group, 11 individuals (3.8%) with different penetration sites suffered ventricular injury. Four (36.3%) of these patients were wounded by bullets, and three (75%) of these individuals died. The other seven (63.7%) sustained wounds from shrapnel fragments, and two (28.5%) of them died. We suggest that the ventricular injuries caused by bullets had a higher mortality rate because of their frequency and their association with diffuse brain damage. In contrast, wounds caused by small pieces of shrapnel took a more benign course.

Some authors suggest that intracranial bone fragments that are not removed can cause infection (7,8). Experimental studies by Pitlyk et al. revealed that such bone fragments did not increase the infection rate itself, but that when scalp or hair accompanied these pieces the rate was 10-fold higher (28). Carey et al. reported two minor and one major complication, and one death after secondary debridement in 103 patients (9). Meirowsky noticed increasing neurological deficits in 4 (3.4%) of 116 reoperated patients (26). These reports indicate that reexploration of intracranial retained fragments carries the risk of increasing a patient's neurological deficits. In his study of 379 patients wounded during the Iran-Iraq War, Aarabi noted that retained bone fragments led to a greater number of CNS infections, but the correlation was not statistically significant. In the Vietnam War, though helicopter evacuation meant that intervention time was shortened to a few hours, the infection rate (5.9%) was higher than that in the Iran-Iraq War (4.7%), where wounds were first treated after an average of 49 hours. Aarabi reported that longer time to intervention did not increase the infection rate (1,3), and emphasized that even when intervention time is long, adequate debridement of infected and contaminated necrotic tissue, dural repair, and antibiotic therapy all serve to decrease the infection rate (3). Brandvold et al. supported less aggressive methods, and reported an infection rate of 11% (7).

In our study, 9 (69.2%) of 13 patients who had cerebrospinal fluid (CSF) fistulas developed CNS infection. Meirowsky et al.(9) noted CSF fistulas in 101 of 1,113 Vietnam War patients with craniocerebral missile wounds caused by bullets. Fifty (49.5%) of these individuals developed infection. In the 1,032 patients who did not have a CSF fistula, only 47 (4.6%) cases developed infection. Aarabi reported a 20-fold higher infection rate in cases with CSF fistulas compared to those without this injury (28). Other authors have reported a higher infection rate associated with CSF fistula, rhinorrhea, and otorrhea in the wound field (15,27). The microorganisms, which are able to reach deep sites in the brain through ongoing CSF fistulas make it difficult to manage this problem. Contamination is unavoidable, even in the face of antibiotic therapy.

Another complication associated with craniocerebral gunshot wounds is posttraumatic epilepsy, which reflects the extent of brain damage and is positively correlated with coma (10). Some reports have linked seizures to increased mortality and morbidity (34,35). Rish et al. has stated that posttraumatic epilepsy is not related to mortality rate, but is another parameter of the extent of brain damage. This condition appears early after a penetrating head injury; the same period when the majority of deaths occur (32). In our series, we observed postoperative seizures in five cases, but there were no associated deaths. Anticonvulsants were used as part of routine medical treatment for all individuals that suffered brain damage, and these were discontinued after 2 years if no seizures were reported.

Another complication, traumatic aneurysm, is noted in the literature as a relatively rare but serious lesion in gunshot wound patients. These are most commonly associated with penetrating wounds of the brain, and are the result of direct damage to the arterial walls. Meirowsky found no aneurysms in his series of 879 patients with craniocerebral missile wounds sustained during the Korean War (24). Hammon reported only 2 traumatic aneurysms among 2,187 penetrating wounds of the brain sustained during the Vietnam War (16). Of 223 consecutive patients who incurred missile injuries and underwent cerebral angiography, Aarabi noted eight cases of traumatic aneurysm. He concluded that patients with penetrating injuries of the brain, especially those that involve intracranial hematomas, should undergo cerebral angiography to rule out vascular brain injuries (2). We performed digital subtraction angiography (DSA) on 35 patients in whom we suspected traumatic aneurysm. These cases included those with wounding objects near the frontotemporal area, those with an intracerebral hematoma seen on CT scan, or those in which an unexpected neurological event occurred. No aneurysms were identified.

CONCLUSION

Our approach to craniocerebral injuries consists of the following steps: careful exploration of the wound; removal of any intracranial hematomas, or superficial or in-driven foreign bodies; debridement of necrotic brain tissue; removal of bullet fragments only when accessible and not requiring approach through uninjured cerebral tissue; and complete closure of the dura, either primary or using a free graft of pericranium, temporalis fascia, or tensor fascia lata. If the missile has traversed deep midline structures, one must be careful to debride only within the missile tract. When CSF leakage occurs after dural repair, lumbar drainage or reoperation must be carried out to prevent CSF fistula formation and CNS infection. In cases where retained bone and metal fragments do not produce signs of infection, patients should be periodically followed up with CT scans. When there is evidence of infection, follow-up surgery must be performed immediately. If an intracerebral hematoma is detected on CT scan, or if there is any suspicion of traumatic aneurysm, DSA should be done at once because a hematoma may harbor and simultaneously obscure an aneurysm. In the intensive care unit, patients' vital functions must be closely monitored. If a patient's state of consciousness deteriorates, CT scans, ICP monitoring, and mechanical ventilation should be applied as needed.

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