Missile Injuries of the Anterior Skull Base

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ABSTRACT

Missile injuries of the anterior skull base usually occur during war or warlike situations. These injuries may be isolated or associated with multiple traumatic injuries. We report 23 such cases managed during military conflicts and peacekeeping operations. All were adult males. Four of these patients sustained bullet injuries; the rest were injured from shrapnel. Eighteen patients had injury to the visual apparatus with permanent blindness. Proptosis was seen in 16, cerebrospinal fluid (CSF) leak from the wound in seven, and CSF orbitorrhea in three patients. Sixteen had irreparable injury to the eye necessitating evisceration/enucleation, and two had retrobulbar optic nerve injury. Three patients were comatose [Glasgow Coma Scale (GCS) 3/15], and 14 had altered sensorium. Six patients were fully conscious. All were investigated by computed tomography (CT), which revealed injury to the eyeball and skull base, orbital fracture, frontal hematoma, contusion, and pneumocephalus. Seventeen patients underwent emergency surgery, and six patients were initially managed conservatively. Neurosurgical management consisted of making bifrontal flaps, craniotomy/craniectomy, debridement, and repair of the base with fascia lata. Reconstruction of the orbital rim was required in three cases. All were managed postoperatively with cerebral decongestants and antibiotics in antimeningitic dosages. There was one death in the postoperative period; outcome was good in 16 and moderate in four patients. Twelve patients had retained intracranial splinters; three of these developed recurrent suppurative meningitis. Of the six patients initially managed conservatively, three were subsequently operated for CSF rhinorrhea. Gross comminution, dural loss, and injury to the frontal scalp often preclude the use of pericranial repair of the skull base. Fascia lata is extremely useful for reconstruction and repair. Anterior cranial fossa injury probably carries a better prognosis; however, there is increased risk of suppurative complications due to breach of air-filled sinuses by the missile and contamination of the intradural compartment, as compared with supratentorial vault injuries not involving the orbit or paranasal sinuses. Three patients who underwent no operative procedure and remain asymptomatic are under follow-up.

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Missile injuries of the anterior skull base are an important subgroup of craniocerebral missile injuries. The missile traverses the facio-orbital planes before penetrating the cranium through the anterior skull base. Less commonly, the missile traverses the frontobasal region and exits through the maxillofacial region. In either situation, cerebrospinal fluid (CSF) spaces communicate with potentially infected air-filled mucosa-lined spaces and patients are prone to infection. Although CMIs are well documented, especially in the military medical literature, anterior skull base injuries caused by missiles are seldom reported as a distinct subgroup.¹ We present our experiences with 23 such patients injured during low-intensity military conflicts and peacekeeping operations.

CLINICAL MATERIAL AND METHODS

Between 1990 and 2002, 157 patients were treated for missile injuries of the brain in three different service hospitals. These injuries were sustained by service personnel during antimilitancy/peacekeeping/low-intensity military operations undertaken by security forces. Twenty-three (15.4%) sustained injury to the anterior skull base. The injuring missiles were shrapnel in 19 cases (five patients were injured by multiple fragments) and bullets in four cases. The sources of shrapnel were grenades, rockets, and improvised explosive devices. Three patients were injured by 7.62 mm bullets fired from AK-47 rifles, and one patient was injured by a 9 mm bullet fired from carbine(sten). Twelve patients reached a medical unit within 1 hour of injury, and the rest reached medical care within 2 to 6 hours. Until the patients were evacuated to a neurosurgical center (which was possible 6 to 48 hours after injury), they were attended by general surgeons.

Assessment

Immediately upon arrival in the medical unit, patients' airway, breathing, and hemodynamic status was assessed (Table 1). The airway was cleared and oxygenation and hemodynamic stabilization were achieved while the injuries were being assessed. None of these patients had significant thoracic, abdominal, or long bone injuries. However, seven required intubation or tracheostomy due to orofacial swelling.

External wounds were small puncture wounds with slight bleeding, gross facial swelling, proptosis, orbitorrhea, and fractures of the maxilla and mandible. Eyeball injuries were managed by an ophthalmic surgeon by evisceration or enucleation.

All patients were evaluated with plain radiography of the skull taken in anteroposterior, lateral, and Towne's views (Table 2). Noncontrast computed tomography (CT) was performed in all patients. One patient also underwent carotid angiography. CT showed cerebral contusion, hematoma, missile track, retained intracranial missile, and pneumocephalus besides showing eyeball injury (Figs. 1–5).

Neurosurgical Management

Seventeen patients underwent emergency neurosurgical procedures for their missile wound. The anterior cranial fossa was exposed through a bicoronal scalp flap and bifrontal craniotomy. The pericranium was preserved so it could be used as a separate

Table 1 Initial Glasgow Coma Scale Scores in 23 Patients with Missile Injuries

GCS Score	No. Patients (%)
12–15	15 (65.2%)
8–11	5 (21.7%)
less than 8	3 (13.1%)

Table 2 Entry Site and Trajectory of Missiles in 23 Patients

Entry Site and Trajectory	No. Patients
Orbitocranial	16 (69.5%)
Transethmoidal	3
Maxilloorbitocranial	1
Submandibulofaciocranial	1
Craniofaciosubmandibular	1
Concussive wave	1

flap. Dural tears were defined and margins were retracted by stay sutures. Only the contused brain was debrided and hemostasis was achieved. Metallic splinters were retrieved only if they were visible during debridement. The cranial base was covered with pericranium/temporalis fascia/fascia lata after the ethmoid fracture was plugged with bone wax and mashed muscle. Convexity dura was closed watertight. The orbital rim was reconstructed in three cases. No biological adhesives were used in any patient. Postoperatively, all patients were given cerebral decongestants. Antibiotics were administered in antimeningitic dosages for 3 weeks. Prophylactic anticonvulsants (phenytoin) were used in all patients.

The patient with the blast injury was treated conservatively for 8 weeks, and CSF rhinorrhea was detected. He underwent evaluation by magnetic

Figure 1 Lateral skull radiograph shows an intracranial splinter, pneumocephalus, and pneumoventriculogram. **Figure 2** Computed tomographic scan shows an orbitocranial hemorrhagic missile track and subarachnoid and intraventricular hemorrhage.

resonance imaging (MRI) to locate the site of the CSF leak, which was related to a fracture of the frontal sinus. He underwent transcranial repair of the skull base. Two patients who had only puncture wounds were initially managed conservatively. They underwent evaluation by Iohexol cisternography for CSF rhinorrhea 4 weeks after the injury (Fig. 6) and then underwent transcranial repair through a bifrontal approach. Of the operated patients, three developed postmeningitic hydrocephalus, which required CSF shunting.

Postoperatively, there was one death: a soldier who had a Glasgow Coma Scale (GCS) score of 3 on arrival. Two patients with initial GCS scores of 3 and 6, respectively, were severely disabled, and three with initial GCS scores of 10 were moderately disabled. Sixteen patients had good outcomes. No patients developed seizures. No retained intracranial missile has migrated.

RESULTS

Postoperatively, one patient whose GCS score was less than 8 with multilobar injury and intraventricular hemorrhage died. Thirteen patients (56.6%)

Figure 3 Computed tomographic scan shows a tangential injury to the anterior skull base and subarachnoid hemorrhage.

recovered well after surgery and were discharged 4 to 6 weeks after injury. Three patients with retained splinters developed meningitis. Overall, the incidence of meningitis was 13.04%. Two

(8%) of these patients later developed a brain abscess and one developed hydrocephalus, but no organism was isolated on CSF culture. Meningitis was treated with antimeningitic dosages of

Figure 4 Computed tomographic scan of the skull base shows metallic splinters in the right orbit and left parasellar region.

Figure 5 Computed tomographic scan shows a retained intracerebral metallic splinter.

Figure 6 Coronal computed tomographic cisternogram shows pneumocephalus, traction on the left ventricular horn, and metallic splinters.

antibiotics (penicillin and chloromycetin, cefotaxime, ceftazidime, netromycin, amikacin). One of the patients developed his brain abscess 5 years after his initial injury and after he had suffered three bouts of meningitis. Three patients (13.04%) with hydrocephalus required ventriculoperitoneal shunting.

Three patients who did not undergo surgical treatment continue to be under observation and are asymptomatic. However, two lost vision in one eye due to injury to the optic nerve or eyeball.

ILLUSTRATIVE CASES

Case 1

A 30-year-old soldier sustained a splinter injury to the inner canthus of the right eye in February 2001. Cranial CT showed a retained intracranial splinter with no significant cerebral injury or hemorrhage. He therefore was managed conservatively. After 3 months, he was readmitted with headache and CSF rhinorrhea. Skull radiography showed the

retained intracranial splinter, pneumocephalus, and air ventriculogram (see Fig. 1). Iohexol cisternography showed a breach in the ethmoidal region and traction on the ipsilateral ventricle (see Fig. 6). He underwent repair of CSF rhinorrhea through a bifrontal approach. The intracranial splinter could not be retrieved. Since then he has remained asymptomatic.

Case 2

A 45-year-old soldier sustained a right orbitocranial splinter injury in 1989 while serving with the Indian Peace Keeping Force. He had no focal motor deficit. His right eye had to be enucleated, and limited debridement of the right frontal region was performed. A metallic splinter could not be removed. CT of the brain showed the retained intraparenchymal metallic splinter (see Fig. 5). Over the next 4 years, he suffered from five bouts of pyogenic meningitis, each of which was treated with antibiotics. In 1993 he was admitted with headache and a 2-week history of hemiparesis. CT showed a thick-walled brain abscess associated with vasogenic cerebral edema and the metallic splinter adjacent to the abscess (Fig. 7). The abscess was excised together with the splinter. Pus was sterile for aerobes and anaerobes. Over the next 6 weeks he recovered from the hemiparesis. However, 6 months later, he was readmitted with headache. On this occasion CT showed hydrocephalus. A ventriculoperitoneal shunt was placed and he has remained asymptomatic.

DISCUSSION

The anterior skull base is the most common region of the skull base injured by a cranial missile. In an autopsy study, this region was injured in 82% of the cases.² Injuries in survivors are usually from a low-energy missile and caused by trauma from direct contact through the missile trajectory. In contrast,

Figure 7 Computed tomographic scan of the patient in Figure 5 obtained 4 years later shows a cerebral abscess and metallic splinter adherent to the abscess wall.

missile injuries involving the middle and posterior cranial fossae are from high-energy missiles, and the victims seldom survive.

The extent of damage in gunshot wounds is proportional to the amount of kinetic energy of the missile dissipated in the wound. Energy deposited along the missile trajectory shatters the bone and lacerates soft tissues.³ A missile traversing the face, orbits, PNS, and skull base creates an open, persistent communication between air-filled, mucus-secreting cavities and subarachnoid spaces.⁴ Skull base fractures involving the frontoethmoidal sinuses may occur without damage to brain due to a blast effect. Such patients may later develop CSF rhinorrhea. High-energy bullets can shatter the skull base without traversing it.² Infection is a real threat. The primary threat of infection is from oropharyngeal commensals (staphylococcus) or gram-positive or gram-negative rods contaminating the wound during entry of the missile.⁵

Injury to the ocular apparatus causes proptosis and complete permanent loss of vision that often requires enucleation.¹ Maxillofacial and orofacial injury can cause respiratory obstruction and hypoxemia, necessitating immediate intubation or tracheostomy. An external CSF leak can occur through

the orbit or nasal cavity. Although CSF otorrhea occurs due to injury of the orbital roof or lateral wall, CSF rhinorrhea is caused by a fracture through the frontal sinus or cribriform plate. However, a missile trajectory through the sinuses, orbit, and skull base may cause the missile to lose its energy before it enters the brain. Hence, although these injuries cause severe maxillofacial injury related to yawing, they often cause less severe brain damage than other trajectories. Only three of the 22 surviving patients (13.63%) had an initial GCS score less than 8, and 14 (66.66%) had a GCS score of 12 or higher.

Diagnostic Imaging

The initial imaging should be by plain radiography of the skull, which may show retained metallic splinters, pneumocephalus, or, rarely, an air ventriculogram. CT is mandatory for all individuals with a gunshot wound of the brain. Besides defining the extent of brain damage, CT is vital for treatment planning and prognostication^{6,7} and three-dimensional imaging with CT may be required to assess the pattern of the fracture and reconstructive procedures. Sequelae of gunshot wounds to the brain may require CT cisternography or MRI for CSF rhinorrhea and carotid angiography to evaluate suspected traumatic aneurysms.⁸ Multilobar injuries (especially bilateral), a transventricular trajectory, obliteration of the basal cisterns, and subarachnoid hemorrhage are poor prognostic indicators. When they are combined with the patient's GCS score a fairly accurate prognosis can be reached.^{7,9-11}

Immediate Surgical Management

Most patients with anterior skull base missile injuries require surgical management. These patients are likely to have open wounds associated with extrusion of brain matter and CSF, with or without signs of an expanding intracranial mass lesion. The sensorium may be altered to various degrees and

focal neurological signs may be present. The aims of surgery in these patients are to evacuate the hematoma, to debride the wound, to achieve hemostasis, and to provide tension-free yet watertight dural closure and repair the skull base while sealing the ethmoidal and frontal air sinuses.

Gunshot wounds to the brain require adequate exposure. For injuries involving the anterior skull base, a bicoronal scalp flap that provides access to a large flap of pericranium and temporalis fascia is desirable. A bifrontal craniotomy that extends to the skull base is performed preserving as much bone as possible. The orbital rim is wired or reconstructed. The frontal sinuses are sealed and exteriorized. Dura is usually lost, necessitating the use of dural substitutes. Autologous tissues are preferred because a synthetic dural substitute can be undesirable in the presence of contamination. For debridement, a less aggressive, brain-conserving approach is advocated.¹² After debridement and hemostasis, CSF leakage from the skull base is addressed. Bone defects are sealed with macerated muscle or bone dust. The anterior skull base is covered with a pericranial-fascia lata flap and the dura is closed watertight. A routine closure is performed.

Antibiotics are continued postoperatively in addition to cerebral decongestants. Continuous lumbar drainage can be used for 48 to 72 hours to prevent CSF leakage from the wound. Patients with ocular and maxillofacial injuries require definitive surgical management.

Delayed Surgical Management

Patients with only a puncture wound, minimal contamination, no neurological deficits, and no gross damage as seen on CT (minimal contusion or hemorrhage and no contralateral shift of midline structures) can be managed conservatively and observed over the ensuing months.^{12,13} The development of complications like meningitis or brain abscess is treated with appropriate antibiotics. Postmeningitic hydrocephalus may require ventriculoperitoneal shunting. CSF rhinorrhea may become

apparent within a few days to weeks of injury. It can be evaluated with CT cisternography to pinpoint the site of CSF leakage if MRI is precluded by the presence of retained intracranial ferromagnetic splinters. In such patients the anterior skull base is repaired through a bifrontal craniotomy.

Retained Intracranial Fragments

With the adoption of a less aggressive approach to treatment, it is likely that several patients will have retained intracranial fragments. The risk of suppurative sequelae is high with patients with a missile trajectory through the skull base, particularly when the air sinuses and the orbit have been breached.^{12,14,15} These patients may have recurrent meningitis, a cerebral abscess, and hydrocephalus.

Prognostic Factors

Prognostic factors include the patient's initial post-resuscitation GCS score, subarachnoid hemorrhage, multilobar trauma, transventricular wounds, and the extent of the wound.¹⁶ The latter is a function of the velocity of the missile. High-velocity missiles (i.e., rifle bullet wounds) inflict a more severe injury than the low-velocity missiles (e.g., pieces of shrapnel).²

CONCLUSION

The anterior skull base is a region of the skull base commonly fractured in cranial missile injuries, and patients with missile injuries of the anterior skull base form a distinct subset of patients with missile injuries of the brain. Missiles traverse the air-filled potentially infected spaces and the visual apparatus may be injured and the upper respiratory passages may be obstructed. Immediate attention to the airway can salvage many of these patients. Management requires a team approach that includes a

maxillofacial surgeon, an ophthalmologist, and a reconstructive surgeon. Evaluation by CT is mandatory. Surgical management is aimed at providing a watertight dura, reduction of intracranial pressure, and control of infection. Outcomes are favorable in survivors. Patients require long-term follow-up to detect sequelae such as meningitis, hydrocephalus, and CSF rhinorrhea.

REFERENCES

1. Jankovic S, Buca A, Basic Z, Zuljan I, Primorac D. Orbitocranial injuries: report of 14 cases. *Mil Med* 1998;163:490-493
2. Betz P, Stiefel D, Hausmann R, Eisenmenger W. Fractures at the base of the skull in gunshots to the head. *Forensic Sci Int* 1997;86:155-161
3. Swan KG, Swan RC. Principles of ballistics applicable to the treatment of gunshot wounds. *Surg Clin North Am* 1991;71:221-238
4. Dillon JD Jr, Meirowsky AM. Facio-orbito-cranial missile wounds. *Surg Neurol* 1975;4:515-518
5. Aarabi B, Taghipour M, Alibii E, Kamgarpour A. Central nervous system infections after military missile wounds. *Neurosurgery* 1998;42:500-509
6. Shoung HM, Sichez JP, Pertuiset B. The early prognosis of craniocerebral gunshot wounds in civilian practice as an aid to the choice of treatment: a series of 56 cases studied by computed tomography. *Acta Neurochir (Wien)* 1985;74:27-30
7. Kaufman HH, Makela ME, Lee KF, et al. Gunshot wounds to the head: a perspective. *Neurosurgery* 1986;18:689-695
8. Cooper PR. Gunshot wounds of the brain. In: Cooper PR, ed. *Head Injury*. 3rd ed. Baltimore: Williams & Wilkins; 1993:355-371
9. Levy M. Outcome prediction following penetrating craniocerebral injury in a civilian population: aggressive surgical management in patients with admission Glasgow Coma Scale scores of 6 to 15 *Neurosurg Focus* 2000;8:Article 2
10. Grahm T, Williams FC, Harrington T, et al. Civilian gunshot wounds to the head: a prospective study. *Neurosurgery* 1990;27:696-700
11. Kennedy F, Gonzalez P, Dang C, et al. The Glasgow Coma Scale and prognosis in gunshot wounds of the brain. *J Trauma* 1993;35:75-77
12. Brandvold B, Levi L, Feinsod M, et al. Penetrating craniocerebral injuries in the Israeli involvement in the Lebanese conflict, 1982-1985: analysis of a less aggressive surgical approach. *J Neurosurg* 1990;72:15-21
13. Bhatote HS, Garg A, Kapoor S, et al. Experiences in the management of splinter injuries of brain in low intensity military conflicts. *Asian Arch Crit Care Med* 1997;46:63-68
14. Aarabi B. Comparative study of bacteriological contamination between primary and secondary exploration of missile head wounds. *Neurosurgery* 1987;20:610-616
15. Bhatote HS. Retained intracranial splinters: a follow-up study in survivors of low intensity military conflicts. *Neurol India* 2001;49:29-32
16. Splavski B, Vrankovic D, Saric G, et al. Early surgery and other indicators influencing the outcome of war missile skull base injuries. *Surg Neurol* 1998;50:194-199

Commentary

The authors have applied the generally accepted principles of skull base surgery to the treatment of missile injuries involving the anterior skull base. We agree with the policy of not removing all intracranial bone and missile fragments if the procedure would carry significant risk to normally functioning brain. They correctly point out that missile injuries of the anterior cranial fossa have better outcomes than injuries further posterior in the skull base. The authors have treated a complicated group of skull base injuries and have achieved quite satisfactory results.

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