Craniocerebral Injuries by Impacted Foreign Objects:
Case Series and Literature Review

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ABSTRACT

Background: Penetrating non-missile craniocerebral injuries are uncommon civilian injuries which present a significant challenge to neurosurgeons. Only limited case-reports are available in the literature with lack of clear guidelines for initial evaluation, surgical intervention, and postoperative care. Objectives: To present our experience with a series of ten patients with penetrating non-missile craniocerebral injuries and review the literature to provide a neurosurgical perspective regarding diagnosis and treatment of these challenging injuries. Patients and Methods: We present a retrospective review of ten patients with penetrating head injury. We have included only the cases with in situ impacted foreign bodies. Early identification and removal of the impacted foreign bodies was achieved within 6-12 hours. Immediate post-traumatic triple antibiotic therapy was given to all patients. Antiepileptic therapy was given to only three patients with post-traumatic seizures (PTS). Results: Outcome was excellent in seven cases, one patient showed left sided hemiparesis with good response to physiotherapy. One patient was reoperated for debridement of retained foreign body fragments and two patients suffered prolonged wound discharge and recovered well after treatment. There were no recorded postoperative seizures or cerebrospinal fluid (CSF) leaks. Conclusion: Early diagnosis, prompt surgical intervention with efficient debridement and proper antibiotic regimen are the key factors for improving the outcome of penetrating craniocerebral injuries.

INTRODUCTION

The cranium can be penetrated by almost every conceivable object. In civilian populations, penetrating craniocerebral injuries (PCIs) are mostly caused by high velocity missile objects while PCIs caused by non-missile, low-velocity objects represents a rare pathology and is usually caused by violence, accidents, or even suicide attempts and self mutilation. Successful management of these injuries requires early recognition and anticipation of diagnostic and therapeutic difficulties.

PATIENTS AND METHODS

Ten patients of low-velocity penetrating head injury with in situ impacted foreign bodies (FBs) were admitted in the neurosurgical department of Benha university Hospital during 2-years period (2011 to 2013). Routine primary survey was done for ensuring clinical stabilization and exclusion of other system involvement, followed by meticulous neurological and local scalp examination. All patients underwent cranial CT scanning in the emergency unit.

Surgical intervention was carried on within 6-12 hours of injury. We started Intravenous broad spectrum antibiotic therapy covering gram-ve, gram+ve and anaerobic organisms on admission and continued for 2 weeks. Three patients only received antiepileptic as they already suffered actual fits and we stopped therapy after 3 months in a gradual withdrawal pattern.

RESULTS

The patient data, circumstances of the injury, management practice and outcome are outlined in the following tables, (Table 1 and 2).
Table 1: Age in years, sex, mode of injury, impacted object, site of penetration.

<table>
<thead>
<tr>
<th>Case</th>
<th>Age, Sex</th>
<th>Object</th>
<th>Mode of injury</th>
<th>Penetration site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18 y/ M</td>
<td>Wood piece</td>
<td>Fall on a wooden object after contralateral head impact</td>
<td>Temporal</td>
</tr>
<tr>
<td>2</td>
<td>1.5 y/ F</td>
<td>Metallic nail</td>
<td>Unclear</td>
<td>Occipital</td>
</tr>
<tr>
<td>3</td>
<td>22 y/ M</td>
<td>Stone</td>
<td>Fall from height, head landed on a stone.</td>
<td>Frontal</td>
</tr>
<tr>
<td>4</td>
<td>10 y/ M</td>
<td>Wood piece</td>
<td>Fall of a wooden object on child's head from 3rd floor</td>
<td>Parietal</td>
</tr>
<tr>
<td>5</td>
<td>44 y/ M</td>
<td>Metal piece</td>
<td>Occupational injury while working with industrial tool</td>
<td>Frontal</td>
</tr>
<tr>
<td>6</td>
<td>25 y/M</td>
<td>Iron rod</td>
<td>Assault</td>
<td>Frontal</td>
</tr>
<tr>
<td>7</td>
<td>35 y/ M</td>
<td>Car locker</td>
<td>Car accident</td>
<td>Fronto-parietal</td>
</tr>
<tr>
<td>8</td>
<td>22 y/ M</td>
<td>Wood cutter  (small axe)</td>
<td>Assault</td>
<td>Frontal</td>
</tr>
<tr>
<td>9</td>
<td>8 y/ M</td>
<td>Stone</td>
<td>Assault by classmate</td>
<td>Occipital</td>
</tr>
<tr>
<td>10</td>
<td>33 y/ M</td>
<td>Motorcycle handle</td>
<td>Road traffic accident</td>
<td>Temporal</td>
</tr>
</tbody>
</table>

Table 2: Investigations, operation done and outcome.

<table>
<thead>
<tr>
<th>Case</th>
<th>CT scan finding</th>
<th>Operation</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Right parietal depressed fracture + air-like hypodensity with bone defect &amp; contusion in left temporal region</td>
<td>Elevation, debridement and reconstruction of the right parietal depressed fracture Left Temporal craniectomy, debridement of bone &amp; wood fragments and duroplasty.</td>
<td>Prolonged wound discharge but made good recovery after treatment</td>
</tr>
<tr>
<td>2</td>
<td>Left occipital hyperdensity with metal artifact.</td>
<td>Left occipital craniectomy</td>
<td>Good recovery</td>
</tr>
<tr>
<td>3</td>
<td>Left frontal hyperdensity with bone defect</td>
<td>Craniotomy, stone extraction, debridement and duroplasty.</td>
<td>Reoperated for debridement of retained fragments</td>
</tr>
<tr>
<td>4</td>
<td>Left parietal air-like hypodensity, bone defect and bone fragment penetrating into the brain</td>
<td>Right parietal craniotomy was done followed by wood extraction, debridement of necrotic tissue and hair</td>
<td>Good recovery</td>
</tr>
<tr>
<td>5</td>
<td>Right frontal hyperdensity, depressed fracture &amp; frontal contusion</td>
<td>Craniotomy, metal delivered, hemostasis &amp; duroplasty</td>
<td>Good recovery discharged without neurological deficit</td>
</tr>
<tr>
<td>6</td>
<td>Right frontal hyperdensity. Extent of brain damage could not be assessed due to severe metallic artifacts</td>
<td>Craniectomy, rod removal, hemostasis &amp; duroplasty</td>
<td>Prolonged wound discharge but made good recovery after treatment</td>
</tr>
<tr>
<td>7</td>
<td>Right fronto-parietal hyperdensity (bone-like) with bone defect and bone fragment penetrating into the brain</td>
<td>Right fronto-parietal craniotomy was done, the metal object was meticulously freed and extracted from the surrounding brain tissue</td>
<td>Improvement of left sided hemiparesis</td>
</tr>
<tr>
<td>8</td>
<td>CT was demanding due to difficult transportation, accommodation in the CT gantry &amp; excess artifacts with seen frontal contusion</td>
<td>Assistant held the handle through the procedures. Craniotomy, slight brain retraction &amp; gentle delivery of the impacted end, hemostasis &amp; duroplasty</td>
<td>Good recovery discharged without neurological deficit</td>
</tr>
<tr>
<td>9</td>
<td>Right occipital hyperdensity with bone defect and air</td>
<td>Craniectomy, delivery of the impacted stone &amp; duroplasty</td>
<td>Good recovery discharged without neurological deficit</td>
</tr>
<tr>
<td>10</td>
<td>Right temporal hyperdensity, depressed fracture, hemorrhage &amp; pneumocephalus</td>
<td>Craniotomy, removal of the object, hematoma evacuation, debridement &amp; duroplasty</td>
<td>Good recovery discharged without neurological deficit</td>
</tr>
</tbody>
</table>
Illustrative Cases

Case 2
The mother of a healthy 1.5 years old girl came to the emergency unit after accidental discovery of hard object in her daughter's head. The girl was fully conscious with good sucking and crying. A small penetrating wound and screw head were identified on the left occipital region. CT scan showed a left occipital hyperdensity with metal artifact. On perative exploration a left occipital craniectomy was performed and the screw was extracted without dural repair, the bone of craniectomy was used for covering the defect and the wound was closed without drain. Postoperative course was uneventful (Fig.1 and 2).

![Fig. 1 a-c: Preoperative x-ray skull and CT brain showing the screw](image)

![Fig. 2 a-c: Operative photographs of the screw penetrating the scalp, (a) and skull (b) and the extracted screw (c)](image)

Case 4
A 10-year-old child was admitted with a wooden piece falling on his head from the 3rd floor. GCS was 15, equal and reactive pupils with no neurological deficit. The wood was embedded in the left parietal region. CT brain showed left parietal air-like hypodensity, bone defect and bone fragment penetrating into the brain. On emergency surgery a right parietal craniotomy was done followed by wood extraction, debridement of necrotic tissue, hair, bone and wooden fragments, bleeding control, irrigation with saline and antiseptics, primary dural repair, bone flap reconstruction and wound closure in layers with drain. Postoperative course was uneventful. Follow-up cranial CT revealed a left parietal hypodensity related to the surgical bed (Fig. 4-6).
Case 7

A 35 years old man was involved in road traffic accident. There was a history of loss of consciousness, vomiting and one seizure attack. By examination the GCS was 12/15, left sided hemiparesis with a visible right fronto-parietal impacted foreign body. CT brain showed right fronto-parietal hyperdensity (bone-like) with bone defect and bone fragment penetrating into the brain. Right fronto-parietal craniotomy was done, the metal object was meticulously freed and extracted from the surrounding brain tissue and noted to be a broken off car locker. Associated contusion and clots were evacuated with irrigation by saline and antiseptics. A fascia lata graft was used for duraplasty followed by bone reconstruction and wound closure in layers with drain. Clinical follow up revealed improvement of left sided hemiparesis without recording of any fits. CT follow-up showed removal of the foreign object with right fronto-parietal hypodense region and acceptable bone reconstruction (Fig.7).
DISCUSSION

Penetrating craniocerebral injuries are relatively uncommon, representing 0.4% of traumatic head injuries.13

Two types of projectiles are implicated in PCI; high velocity missile projectiles where tissue cavitations and shock waves are the main causes of complex injuries and poor prognosis, 1, 19 and non-missile projectiles with impact velocity <100 m/second where direct disruption and laceration of tissues are the main causes of the localized primary injury and better prognosis.6, 19, 20 These non-missile projectiles include different metallic, wooden, stony, glassy and other industrial or environmental objects.3, 6, 12, 21

The consequence of a PCI is determined by a number of characteristics that include the properties of the penetrating object (type, velocity, size..... etc),19 the characteristics of intervening tissues (skull, muscle, mucosa, etc.)20, the angle of approach, the site and depth of initial injury, anatomic and neurovascular structure of the passage11, 13 and the presence of any secondary projectiles, such as bone or metallic fragments.19

Most reported cases described trajectories through the orbit, skull base foramina, or areas of thin bone such as the temporal squama.31 Nevertheless, if a sharp implement is thrust forcefully enough it will penetrate any part of the skull vault,19 and this is the case in our review in which the impacted foreign object was wooden in two cases, stone in two cases, and metallic in six cases.

The term “tangential injury” is given to the lesions that do not cross the inner table, and thus causes no injury to the dura mater. Nonetheless, this type of injury can cause intracranial lesions, such as subdural and epidural hematomas, contusions and traumatic subarachnoid hemorrhage (SAH).11 Of the ten patients, one patient had tangential lesions with penetration of the outer table and fracturing the inner one without penetration. But in all other cases the object crosses the skull cap with variable degrees of dural (in nine cases) and cortical (in seven cases) injuries.

Penetrating wooden object presents significant challenges with regard to high infection rates due to its softness and porosity, difficult radiographic identification and frequent fragmentation into microscopic retained particles.2 Penetrating glass injury is very rare. Glass fragments may break off within the wound, and should be thoroughly investigated to confirm the presence of splinters.28 The metal artifact generated by impacted metallic objects may cause distortion of CT images and inadequate assessment of the extent of brain injury.12 Stony materials are of similar chemical structure to bone so may be missed and show no artifacts in standard scans.3

Big sized objects pose difficulties in patient transportation with possible movement and more injury, in CT examination because of the limited space in the CT Gantry and in planning surgical management.21 One
of our cases an assistant was holding the impacted object throughout the procedure thus preventing any undue movement. This patient was operated without preoperative CT, the space in the CT Gantry did not accommodate the patient with the axe tip impacted in his head.

The risk of posttraumatic epilepsy is high probably due to direct cortical injury with subsequent scarring. Posttraumatic seizures (PTS) has been classified, as immediate (manifesting at <24 hours), early seizures (manifesting <1 week after injury) and late seizures (manifesting >1 week after injury). Factors that showed significant relationship to PTS were; GCS at presentation, mode of injury, transventricular injury, focal neurological deficit, infections, early-onset seizures, posttraumatic amnesia, unevolved depressed fracture and dural penetration by injury. In this series, three patients with metallic foreign objects impacted deeply in the brain presented with immediate seizures.

Vascular complications of PCI ranged from 5 to 40% in various reports. Common vascular complications include pseudo- or true traumatic aneurysms, arteriovenous malformation, SAH and vasospasm. In this series all trajectories were through the skull vault away from major vascular territories hence no vascular complications were recorded.

Infectious complications are not uncommon after PCI, and they are also associated with higher morbidity and mortality rates. Risk factors of infection include deep or multifocal brain injury, intracranial retained bone and metallic fragments, CSF fistulae, air sinus wounds, transventricular injuries, or wounds crossing the midline. Staphylococcus aureus is the most frequently associated organism. Potential infections include scalp sepsis, osteomyelitis, epidural and subdural empyemas, meningitis, ventriculitis, cerebritis, and cerebral abscess.

Plain radiograph is not routinely recommended being largely precluded by computed tomography (CT). Plain radiograph was used in two cases only in this series.

CT is the most valuable radiological modality for evaluation of patients with PCI. All PCI patients should have unenhanced standard axial views with bone and soft tissue windows even with trivial scalp laceration. Coronal and sagittal sections may be added for better assessment. It provides detailed information about the injury (location, trajectory and relations of the foreign body), presence of secondary projectiles (bone or foreign body fragments) and presence of associated intracranial lesions (e.g. Hemorrhage or contusion). It helps to define the prognosis. Unfavorable prognosticators are: bilateral hemispheric, multifocal or brainstem injury, transventricular trajectory, cerebral lesion with mass effect and secondary projectiles away from the trajectory. Postoperative CT scan can be helpful in evaluating the development of infection, delayed, hematomas and the presence of residual foreign body or bone fragments. In this series, preoperative CT with (coronal, sagittal and 3D reconstruction) was done in nine patients, and was not done in one patient with axe tip impacted on his head as this was technically demanding. Postoperative CT scan with bone window was routinely done for all patients.

Magnetic resonance imaging (MRI) is not recommended for use in PCIs, as it is time consuming, less accessible, inadequate for bones and can be potentially dangerous in ferromagnetic objects. However, MRI can be useful for nonmetallic foreign bodies e.g. wooden object. MRI was not used in this series.

Removal of the foreign body outside the operating room is discouraged because of the possibility that it may be tamponading an injured vessel leading to fatal hemorrhage. The protruding object should also be stabilized during transportation, evaluation and treatment to prevent further injury. Surgical treatment should be performed within 6-12 hours of the injury to decrease the risk of infectious complications.

While designing the incision the neurosurgeon should consider; incorporation of the area that needs debridement, preserving the vascular supply of the flap and planning the final reconstruction of the dura, skull and scalp. Which is best; craniotomy or craniectomy is still debatable with no reported significant statistical difference between these two procedures.

Craniotomy was used in six patients, while craniectomy was used in the other four patients in our study. The foreign object should be carefully removed in the direct reverse path of trajectory without rocking movements to avoid further damage. Any haematoma should be evacuated with debridement of contaminated debris, necrotic tissues (hair, scalp, bone, or dura), any accessible bone or foreign body fragments with avoiding removal of distant bone or foreign body and minimizing the degree of cortical debridement especially in the eloquent areas of the brain. Only one patient presented with left hemiparesis due to impacted car locker within the motor cortex.

When the trajectory of the object violates an open air sinus, the sinus mucosa is removed with obliteration of the cavity with e.g. abdominal fat, muscle or pericranium.

The dura should be closed in a watertight fashion either by direct closure or by using autologus grafting materials e.g. pericranium. Synthetic grafts, being a foreign body, become a potential source of infection.

Temporary CSF diversion should be considered in remote or refractory CSF leaks. Permanent CSF
diversion may be indicated in hydrocephalus. In this series, there was no need for CSF diversion.

Every effort should be done to avoid secondary brain insults by aggressive intensive care management.

Prophylactic antiepileptic treatment is controversial. Recent data indicate that anti-seizure medications are capable of reducing the incidence of early posttraumatic seizures, but incapable of preventing late-onset seizures. In our series, three patients only received antiepileptic as they already suffered actual fits and we stopped therapy after 3 months in a gradual withdrawal pattern.

There is a considerable variation in the preference for antibiotic regimen for prophylaxis in PCI patients. Some have recommended the use of intravenous ceftriaxone, vancomycin and metronidazole for a minimum of 6 weeks. The “Infection in Neurosurgery” Working Party of British Society for Antimicrobial Therapy recommended the following regimen: intravenous co-amoxiclav or cefuroxime with intravenous metronidazole started as soon as possible after injury and continued for 5 days postoperatively. Based on the available literature, we recommend maintenance antibiotic prophylaxis for at least 14 days in all of our patients with no infection in a follow-up period of one month.

Dealing with PCIs may appear straightforward; nevertheless, it is still characterized by unique challenges and controversial issues e.g. Aggressive versus conservative approach in comatosed patients with multifocal or extensive brain damage minimal versus extensive debridement for removal of devitalized and preservation of viable brain tissue and management of deeply located foreign body or bone fragments.

CONCLUSION

Non-missile PCIs are not uncommon in developing countries especially in the rural setup. Appropriate practice suggests a high index of suspicion and meticulous examination of the scalp even in presumed trivial wounds. CT scans especially with 3D reconstruction are the mainstay diagnostic tool for evaluating PCI. Immediate neurosurgical exploration (under umbrella of antibiotics) with appropriate debridement and anatomical reconstruction and intensive postoperative follow up are vital for achieving favorable prognosis.

REFERENCES

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