Skull Base Penetration Due to Cervical Impalement Injury: A Case Report and Review of the Literature

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ABSTRACT

Impalement injury is a rare type of trauma, and the management should be performed carefully. In cases with impalement injuries, the area of injury and crush might be extensive because the penetrating object itself is generally large and long. Herein, we report our experience with a rare case of cervical impalement injury caused by an iron reinforcing bar penetrating the optic canal and thereby causing brain contusion. A 32-year-old man fell while working at a construction site and sustained an injury due to an iron reinforcing bar that penetrated his right neck. On arrival at the hospital, consciousness was clear and the bar was removed by himself. The patient had lost the sight in his right eye, and cerebrospinal fluid (CSF) rhinorrhea was present. Based on the results of computed tomography (CT) of the head and neck, the bar was thought to have passed through the right mandible and the right optic canal and penetrated the frontal lobe. Surgical repair of frontal base was performed using femoral fascia, completely stopping the CSF leak. The patient was discharged on the 31st hospital day walking independently. In our present case, the top of a foreign body was reached an intracranial site. Impalement injuries require detailed assessment of the injury sites because outcomes depend on the severity of injuries at surrounding anatomical structures. Multiple planar reconstruction using recent multidetector row CT scanning was considered to be useful for the assessment of penetrating routes and injury severity.

KEYWORDS

Impalement Injury; Penetrating Injury; Skull Base; Multiple Planar Reconstruction

1. Introduction

Among penetrating injuries, those caused by a relatively blunt object are called impalement injuries. Impalement injuries are sustained by falling onto bar-like objects such as stakes and iron rods or by being stuck by projectiles from an explosion. The penetrating objects are generally larger than knives, and the area of injury and crush is extensive. Moreover, the penetrating objects are frequently contaminated. Impalement injury is a relatively rare type of trauma, and commonly accompanied by injuries involving the bladder or rectum. There are a few reports on head and neck impalement injuries, and in which the penetrating routes to intracranial regions were discussed [1,2]. Of these, few cases are reported previously on cervical impalement injuries that penetrated the skull base to reach the intracranial region [3,4]. Herein, we report a rare case of cervical impalement injury caused by an iron reinforcing bar that penetrated the optic canal to reach the frontal lobe. The literature on head and neck impalement injuries is also reviewed.

2. Case Report

A 32-year-old previously healthy man slipped and fell while working at a construction site, and sustained an impalement injury due to an iron reinforcing bar 13 mm in diameter protruding upward about 70 cm from the concrete foundation that penetrated his right neck at a
point approximately 3 cm below the right angle of the mandible (Figures 1(a)-(b)). The penetrated bar was extracted by himself. Two and half hours after the injury, the patient was arrived at the emergency room of our hospital. On arrival, the Glasgow Coma Scale was 15 (E4, V5, M6), the visual acuity in his right eye had been completely lost, but there were no other neurological abnormalities. The pupil was 4 mm in the right eye and 3 mm in the left eye. The direct light reflex was absent in the right eye, and the indirect light reflex was absent in the left eye. The injury was present in the right neck at a point approximately 3 cm below the angle of the mandible (Figure 1(c)). Epistaxis and cerebrospinal fluid (CSF) rhinorrhea was recognized. Transnasal fiberscope examination revealed the swelling at the posterior wall of the nasopharynx, but the point of penetration in the pharyngeal wall could not be found. Computed tomography (CT) of the neck showed emphysema along the carotid artery to the level of the cricoid cartilage. It also revealed that emphysema continued from the neck to the frontal lobe through the sphenoid sinus (Figures 2(a)-(b)). CT of the head showed mixed densities in the right frontal lobe considered to be bone fragments and contusional brain (Figure 2(c)). Based on these findings, the reinforcing bar appeared to have penetrated the neck below the right mandible, the right posterior ethmoid and sphenoid sinuses, the right optic canal, and the frontal base (Figure 2(d)). The bar entered from the neck was penetrated approximately 20 cm from the entry site. Three-dimensional (3D)-CT angiography and cerebral angiography showed no extra-vascular leakage of contrast medium (Figures 2(e)-(f)).

After admission, a continuous CSF rhinorrhea had not been improved. On the 3rd hospital day, surgical repair of the frontal base was performed. After bifrontal craniotomy, the damage of the dura mater and the brain parenchyma at the right frontal base was identified. An injured cortical vein, hematoma, and a few bone fragments was recognized around the surface of the brain (Figure 1(d)). Removal of hematoma and debridement of the contusional brain were performed. The femoral fascia was used for duraplasty, and the paranasal sinus was covered with a periosteal flap, and then cranioplasty was performed. Ceftriaxone sodium was administered, starting on the day of admission, for 11 days. Postoperatively, no neurological abnormalities had been developed except unilateral visual loss and mild neuropsychological deficit. On the 31st hospital day, he was discharged walking independently and has been doing well without recurrence of CSF rhinorrhea or the occurrence of infectious complications.

3. Discussion
3.1. Head and Neck Impalement Injuries
In total, 31 patients including our case with head and neck impalement injuries were previously reported, and
that were reviewed [1-25]. There were 26 men and 5 women, and the mean age was 36.4 years. The most frequently reported causative event was a fall, in 17 patients, followed by accidental impacts in 7, traffic accidents in 4, and violence in 3. The impaling objects were metallic in 25 patients and wooden in 6. Thus, although the head and neck impalement injury is rare, most of the cases are male of adolescence of the workman’s accident, and social influence is large. The most frequently reported route was trans-orbital, in 12 patients, followed by trans-facial in 9, trans-cervical in 8, and trans-oral in 2. The 8 cases of trans-cervical route including our case were summarized in Table 1. Of these, the directions of impalement were divided into two groups: cranial course (the impaling objects entered cranially, including cases with impalement of the orbit and paranasal sinuses; n = 5) and pharynx/oral cavity course (the objects stopped within the pharynx or oral cavity; n = 4). All of the impaling objects entering via the trans-cervical cranial course were extracted by the patient himself/herself before visiting a hospital. Major arterial injuries occurring along the route of penetration critically impact the prognosis of impalement injury patients. In the present review of patients with impalement injuries, none died as a direct consequence of cervical arterial injuries in the neck or extracranial regions through which the object had passed. Survival was dependent on the presence or absence of intracranial injuries (vascular injuries in the brain stem and intracranial regions) by a foreign body at any of the points of penetration. When the top of a foreign body penetrated the pharynx or oral cavity, the clinical problem was an airway emergency due to the foreign body itself, bleeding, or edema [1,6,9,10,23].

3.2. Penetrating Neck Injuries

From the viewpoint of penetrating neck injuries, all the penetrating neck injuries are classified according to injury location into three zones [26]. Zone I (lower part) is from the cricoid cartilage to the suprasternal notch and the clavicle, containing large vessels in the thoracic outlet, vertebrae, vertebral artery, lung, trachea, esophagus, spinal cord, and thoracic duct. Zone II is the widest, from the angle of the mandible to the rostral of the cortical cartilage, including the jugular vein, vertebral and common carotid arteries, inner and outer branches of the carotid artery, trachea, esophagus, larynx, and spinal cord. The injury of our patient was classified into zone II. Zone III is above the angle of the mandible to the cranial base, containing the jugular vein, vertebral artery, the distal part of the internal carotid artery, and the pharynx. Treatments, management, and prognoses are zone-dependent. Vascular injuries in the mediastinum may occur in zone I, resulting in difficulty controlling bleeding, and zone I injuries have the highest mortality rate. For zone III injuries, an operative treatment may be indicated because these injuries affect the cervical artery or lower cranial nerves. Moreover, penetrating neck injuries are characterized by combined risks including those for laryngotracheal, vascular, pharynx, and cranial nerve injuries. The overall mortality is assumed to be 3% to 10% [27]. Patients with unstable airway, respiratory and circulatory dynamics, widespread subcutaneous emphysema, pulsatile bleeding, or deterioration of neurological findings are considered to be in an unstable state, and emergent surgical intervention should be taken into consideration [28]. Severity of injury is difficult to determine based on the superficial appearance of the injury. Entire routes and

### Table 1. Summary of patients with neck impalement injury by blunt weapon.

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Age/Sex</th>
<th>Cause</th>
<th>Weapon</th>
<th>Self Removal</th>
<th>Route</th>
<th>Consciousness Impairment</th>
<th>Brain Contusion</th>
<th>Site</th>
<th>Neurological Deficit &amp;ADL</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Nakai K</td>
<td>61/M</td>
<td>Fall</td>
<td>Iron Reinforcing Bar</td>
<td>+ A, C, D</td>
<td>+ FL</td>
<td>GCS14</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>2001</td>
<td>Wada T</td>
<td>15/M</td>
<td>Fall</td>
<td>Iron Reinforcing Bar</td>
<td>+ A, C, D</td>
<td>Somnolent</td>
<td>GCS14</td>
<td>+ FL</td>
<td>-</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>2002</td>
<td>Hoshi J</td>
<td>55/M</td>
<td>Fall</td>
<td>Iron Reinforcing Bar</td>
<td>- A, B, C</td>
<td>- Bilateral Blind</td>
<td>GCS14</td>
<td>+ FL</td>
<td>-</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>2007</td>
<td>Aoyagi Y</td>
<td>85/M</td>
<td>Fall</td>
<td>Iron Pole</td>
<td>- A</td>
<td>-</td>
<td>GCS14</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>2009</td>
<td>Mansour AM</td>
<td>51/M</td>
<td>Fall</td>
<td>Iron Reinforcing Bar</td>
<td>- B, C, A</td>
<td>-</td>
<td>GCS14</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>2010</td>
<td>Satou H</td>
<td>51/M</td>
<td>Fall</td>
<td>Chip Wood</td>
<td>- A</td>
<td>-</td>
<td>GCS14</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Alive</td>
</tr>
<tr>
<td>2011</td>
<td>Perdekamp MG</td>
<td>78/F</td>
<td>Fall</td>
<td>Bamboo</td>
<td>+ A, D</td>
<td>Unilateral Visual Loss, Mild Neuropsychological Deficit</td>
<td>GCS14</td>
<td>+ TL</td>
<td>Hemiparesis</td>
<td>Dead</td>
<td></td>
</tr>
</tbody>
</table>

Route: A: neck/pharynx, larynx, B: orbit, C: paranasal sinus, D: brain parenchymal; Consciousness Impairment: GCS; Glasgow Coma Scale, Site of brain contusion: FL; frontal lobe, TL; temporal lobe.
areas including the entry point based on the type and penetrating angle of an impaling object should be taken into consideration for assessment. CT and 3D-CT angiography are useful in screening patients for tracheopharyngeal or vascular injuries [5,6,29-32]. Especially, 3D-CT using the multiple planar reconstruction (MPR) method can produce an image from an arbitrary angle along the impaling route. Therapeutic protocols for head and neck impalement injuries have been developed incorporating these imaging modalities [33-37]. In these protocols, angiography or contrast-enhanced CT could not be performed for preoperative assessment because the foreign body interfered with scanning. In these patients, the presence or absence of vascular injury and tracheosophageal injury should be identified directly during endoscopic examinations or operations.

3.3. Skull Base Penetration of Impalement Injury

The features of skull base penetration of impalement injury are as follows: there is a blunt injury aspect accompanying contusion of the brain parenchyma due to the blunt top of the object; major vessels, which are relatively flexible and elastic, are seldom injured when an object penetrates at low speed. Even if major vessels are injured, it might not result in fetal bleeding providing a tamponade effect so long as the foreign body is not removed [1,6,10]. However, when the object reaches the brain stem or cerebellum in the posterior fossa or injures the venous sinus, removal of the penetrating object may be life-threatening [2,18,21]. Even in cases with supratentorial lesions, assessment of vascular injury before treatment is essential because there may be an accompanying pseudoaneurysm, intraventricular hematoma, or subarachnoid hemorrhage [3,38]. Particularly, since the orbital hiatus (posterior wall type) is anatomically located adjacent to the cranial nerves, internal carotid artery, pituitary gland, and cavernous sinus, a fatal vascular injury, brain stem injury, or cranial nerve palsy may develop due to the impaling foreign body [8,17,23].

There is no definite evidence with respect to surgical treatment for penetrating injuries. The retention of intracranial foreign bodies and contaminated bone fragments, CSF leaks, air sinus injuries, and trans-ventricular injuries may create a risk for late-onset infectious complications [39]. Therefore, hemostasis, debridement, and duraplasty are sometimes needed for preventing secondary complications including meningitis and brain abscesses [40]. In the present case, because the size of the defect in the frontal skull base was wide and the CSF leak was continued to be unlikely to resolve spontaneously with conservative therapy, a radical operation was performed. It is noteworthy that intracranial infections often develop during the chronic phase, so as to long-term follow-up should be necessary [41,42].

4. Conclusion

We report our experience managing a case with a cervical impalement injury penetrating skull base due to an iron reinforcing bar. Although the cervical impalement injury is rare, most of the cases which reviewed are male of adolescence of the workman’s accident. Survival is dependent on the presence or absence of major intracranial vascular injuries, brain stem injuries, and airway emergencies. Therefore, 3D-CT using the MPR was useful for detecting the penetrating route of the object and establishing the evaluation of surrounding anatomical structure.

REFERENCES

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