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Penetrating Orbitocranial Injuries in the Republic of Korea

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Conflict of Interest
The authors have no financial conflicts of interest.

ABSTRACT

Objective: Penetrating brain injury occurs when an object enters the skull and pierces the brain. These injuries can damage small or large parts of the brain, are life-threatening, and require emergency care. This study is a summary of penetrating head injuries at our hospital and an analysis of their treatments and prognoses.
Methods: Patients with penetrating brain involving the orbit and/or cranial region were recruited among patients with trauma who visited our regional trauma center between 2019 and 2022.
Results: Eight patients with penetrating brain injuries were enrolled. One patient was female; the median age was 53 years (range, 24–72 years). Five patients with Glasgow Coma Scale (GCS) scores of 14 or 15 showed no major vessel injury or midline intracranial involvement on imaging and were discharged safely. The other three patients with suspected major vessel injuries and midline involvement did not survive.
Conclusion: The greatest influences on patient prognosis were the area of damage and level of consciousness, along with the GCS score at the time of the visit. The probability of survival is extremely low if the midline structure is damaged.

Keywords: Traumatic brain injury; Penetrating brain injury; Orbit; Glasgow Coma Scale; Foreign body

INTRODUCTION

Penetrating brain injuries occur when an object enters the skull and pierces the brain. These injuries can damage small or large parts of the brain, are life-threatening, and require emergency care. Penetrating brain injuries are mostly caused by impact with high-velocity objects, which result in more complex injuries and higher mortality than contact with low-velocity objects. Penetrating brain injury caused by non-missile, low-velocity objects tend to have a better outcome because of the more localized primary injury. Gunshot wounds (GSW) are the primary Injury caused by high-velocity wounds, while low-velocity wounds include injuries caused by sharp knives or axes.[14] Korea has very strict gun regulations, so gunshot wounds are very rare. Also, many traumatic brain injuries are related to blunt objects, and

penetrating injuries are rare.[6] Therefore, it is unusual for neurosurgeons to encounter patients with penetrating injuries to the head.

Our hospital is a regional trauma center and treats many patients with severe trauma. This study is a summary of penetrating head injuries at our hospital and an analysis of treatments and prognoses.

MATERIALS AND METHODS

Patients with penetrating brain involving the orbit and/or cranial region were collected among trauma patients who visited our regional trauma center from 2019 to 2022. Penetrating orbitocranial injuries were defined as traumatic injuries that occur when an object enters the head and damaged the orbit or the brain. All typical epidural or subdural hematoma related to blunt injury was excluded. The medical records of included patients were reviewed. The etiology of trauma, patient demographics, test results, and treatments and prognosis were analyzed, and the cause of injury was identified. A case passing through the midline sagittal on the radiologic image was defined as having a midline involvement. In addition, a case with damage to the large arteries around the Willis circle or cerebral sinuses was defined as having a major vessel injury.

The study protocol was reviewed and approved by the Institutional Review Board of the Catholic University of Korea (UC22RISI0014). As a retrospective study, the Institutional Review Board approved a request to waive the need for informed consent.

RESULTS

Eight penetrating brain injury patients were enrolled in this study. One was female, and the median age was 53 years (range 24–72 years).

The trauma involved the orbit in four cases and the cranium in seven cases. The injury penetrated through the orbit in three cases, through the cranium in three cases, through the nostril in one case, and through the axilla in one case. Four patients had a Glasgow Coma Scale (GCS) of 15 at the emergency room (ER) visit, one had a GCS of 14, one had a GCS of 13, and the other two had a GCS of 3. Five patients with GCS scores of 14 or 15 showed no major vessel injury or midline intracranial involvement on imaging and were discharged safely. Meanwhile, the other three patients with suspected major vessel injury and midline involvement did not survive. The patients were all prescribed prophylactic antibiotics (ceftriaxone + metronidazole) after visiting the ER, and no infections were reported during treatment.

The demographic and clinical results of the patients are organized in **TABLE 1**, and each case is summarized below.

Illustrative cases

Case 1

A 41-year-old female patient was admitted to the ER with a tree branch lodged in her right nostril as a result of a fall while hiking (**FIGURE 1A**). She was mentally alert at arrival, and there was no neurologic deficit. The brain computed tomography (CT) scan performed in

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TABLE 1. Demographics and clinical results of the patients with orbitocranial penetrating injury

Case	Etiology	Age	Sex	Initial GCS	Major vessel injury	Midline involve	mRS
1	Branch lodged in the frontal base through the nostril	41	F	15	(–)	(–)	0
2	Ballpoint pen stuck in the orbit and nasal cavity	60	M	15	(–)	(–)	0
3	Stabbed in the orbit with a sword following a displacement of the anterior clinoid process	24	M	15	(–)	(–)	1
4	Stabbed in the orbit with a drill bit	60	M	15	(–)	(–)	0
5	Gunshot wound to the brain from the parietal to occipital	72	M	14	(–)	(–)	2
6	A rebar penetrating the brain from the left frontal lobe to the right orbit	51	M	13	(+)	(+)	6
7	An ax stuck in the middle of the head	55	M	3	(+)	(+)	6
8	As the rebar penetrated through the foramen magnum from axilla	48	M	3	(+)	(+)	6

GCS: Glasgow Coma Scale, mRS: modified Rankin Scale.

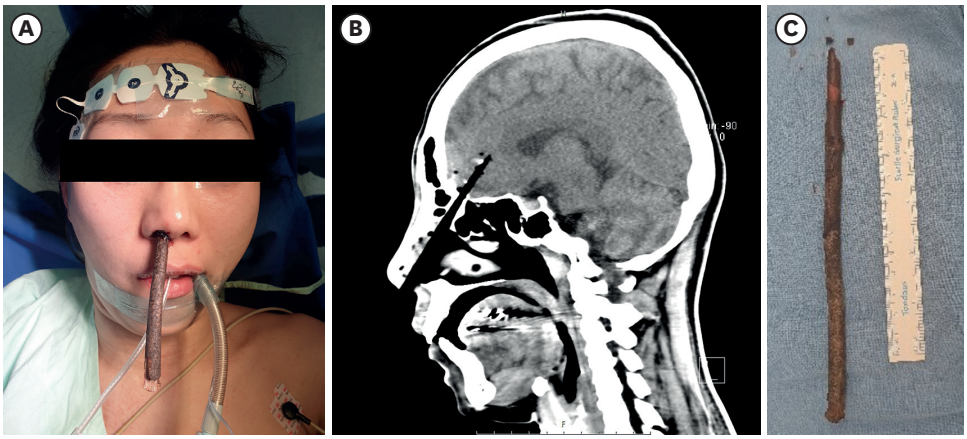

FIGURE 1. Illustrative case 1.
A 41-year-old female patient with a tree branch lodged in her right nostril as a result of a fall while hiking. (A) On brain computed tomography scan, an 18-cm-long tree branch crossed the ethmoid sinus and entered the intracranial space. (B, C) Emergency endoscopic foreign body removal and frontal base reconstruction were performed. On the ninth day of postoperative hospitalization, she was discharged without neurological damage.

the ER showed a tree branch about 18 cm long crossing the ethmoid sinus and entering the intracranial space (**FIGURE 1B & C**). There was no significant cranial damage other than that to the base of the frontal lobe, and major vessel injury was not suspected. Emergency endoscopic foreign body removal and frontal base reconstruction were performed. On the 9th day of postoperative hospitalization, she was discharged without neurological damage.

Case 2

A 60-year-old schizophrenic male patient who was transferred from another hospital visited our ER with a ballpoint pen stuck in his left orbit after a fight. Upon arrival, the patient was mentally alert, and no specific neurological symptoms were observed, but congestion and swelling of the left eye were noted. A brain CT scan showed tubular penetration into the left eyeball and medial rectus muscle to the left ethmoid and right sphenoid sinus, with residual metallic spring (**FIGURE 2A**). We suspected remaining foreign bodies in the endonasal cavity. The left eye foreign body was removed through the external wound of the eyelid crease. Nasal cavity foreign body removal surgery was performed through an endoscopic endonasal approach (**FIGURE 2B**). He was discharged without major complications on the 13th day after surgery. At the outpatient visit 2 months later, there was no visual impairment or limitation of external ocular movement.

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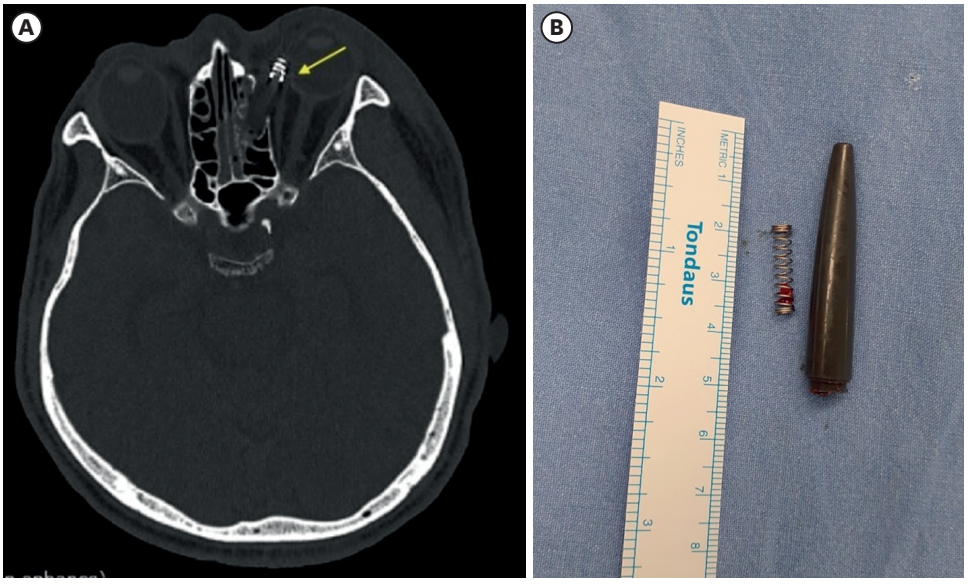

FIGURE 2. Illustrative case 2.
A 60-year-old male patient visited the emergency room with a ballpoint pen penetrating the left orbit. Brain computed tomography showed tubular penetration with residual metal spring. (A) Foreign body removal surgery was performed on the left eye through the external wound of the eyelid crease (yellow arrow). Nasal cavity removal surgery was performed through the endoscopic endonasal approach. (B) The patient was discharged without major complications on the 13th day after surgery.

Case 3

A 25-year-old male patient visited the ER after being stabbed in his right eye while practicing medieval swordsmanship. Upon presentation, he was alert, but extraocular muscle (EOM) limitation was observed in the right eye at upward gaze. The sword was removed before visiting the ER (**FIGURE 3A & B**), but a fracture of the comminuted, posterior orbital roof; a fragment of displaced anterior clinoid process, and intraorbital hemorrhage were observed on brain CT. In addition, extensive pneumocephalus was observed intracranially (**FIGURE 3C**). Fortunately, there was no injury to the internal carotid artery. Bone fragment removal and dural repair were performed through a subfrontal approach. The eyelid and periorbita were reconstructed by a plastic surgeon. On the 17th day after surgery, he was discharged with EOM limitation and ptosis in the right eye. At his outpatient visit 3 months later, all symptoms had improved.

Case 4

A 60-year-old male patient fell from a ladder and was stabbed in the forehead by an electric drill. Upon arrival in the ER, he was alert and had no specific neurological symptoms. The external wound at the right eyelid showed a penetrating injury of the drill bit through the orbit (**FIGURE 4A**). On brain CT, fractures of the comminuted, right inferior frontal bone and pneumocephalus were observed in the right frontal area (**FIGURE 4B**). Damage to other significant regions was not suspected. There was no foreign body in the intracranial region, so no other surgery was performed, and only antibiotics were prescribed. The patient was discharged without specific neurological symptoms on the eighth day following admission.

Case 5

A 72-year-old male patient visited the ER with gunshot wounds to the abdomen and head. On arrival, he was mildly drowsy; CT of the abdomen showed pneumoperitoneum and hemoperitoneum, and brain CT showed a metallic foreign material at the right posterior

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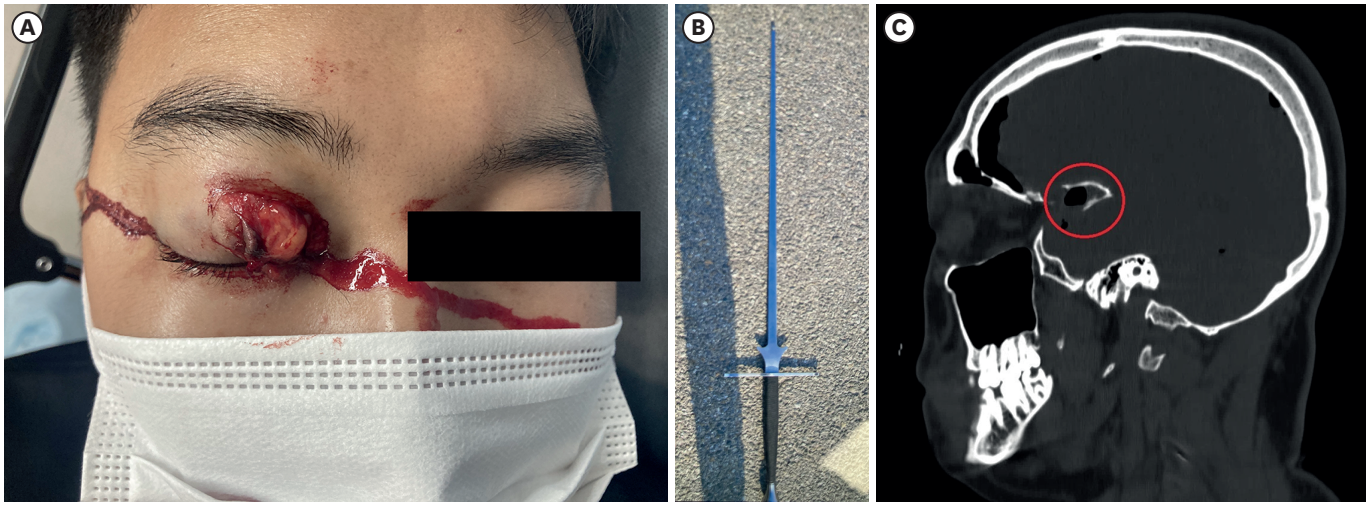

FIGURE 3. Illustrative case 3.
A 25-year-old male patient was stabbed in his right eye. (A, B) The penetrating material was removed, but fracture of the comminuted, posterior orbital roof and a bony fragment of the anterior clinoid process displacement (red circle) was observed on brain computed tomography. (C) There was no injury to the internal carotid artery. Bone fragment removal and dural repair were performed through the subfrontal approach. The eyelid and periorbita were reconstructed by plastic surgeon. On the 17th day after surgery, he was discharged with extraocular muscle limitation and ptosis in the right eye.

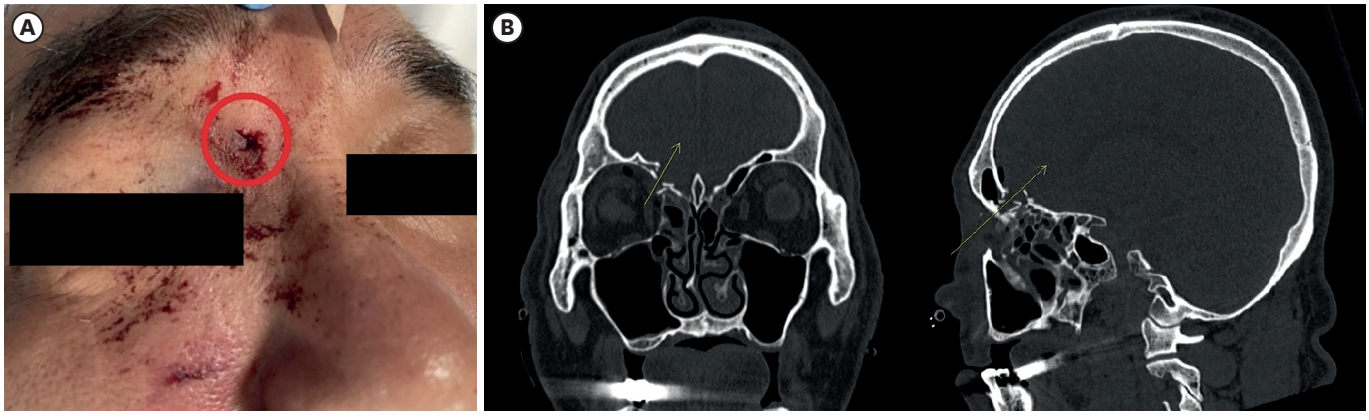

FIGURE 4. Illustrative case 4.
A 60-year-old male patient visited the emergency room after being stabbed in the forehead by an electric drill. The external wound at the right eyelid showed a penetrating drill bit injury through the orbit. (A) The brain computed tomography showed fractures of the comminuted, right inferior frontal bone. (B) There was no foreign body left in the intracranial space, so no other surgery was performed, and only antibiotics were prescribed (traumatic trajectory, yellow arrow).

parietal lobe with elongated intracerebral hemorrhage (ICH) (**FIGURE 5A**). The material did not invade the eloquent area or impact major vessels. The patient's blood pressure was 80/50 mmHg; therefore, bowel resection and primary closure were performed for a bowel perforation. Afterward, a craniotomy was performed by a neurosurgeon. Confirming the location of the foreign body using ultrasound, the bullet was removed by approaching through the shortest trajectory (**FIGURE 5B**). The entry point wound was reconstructed by a plastic surgeon. The patient was treated in an intensive care unit and is receiving rehabilitation treatment with cane-assisted ambulation.

Case 6

A 51-year-old male patient visited the ER after a 20-m rebar penetrated his headgear and head while on a construction site (**FIGURE 6A**). At arrival, he was mentally drowsy and partially obeyed commands. Brain CT showed diffuse cerebral hemispheric edema and the

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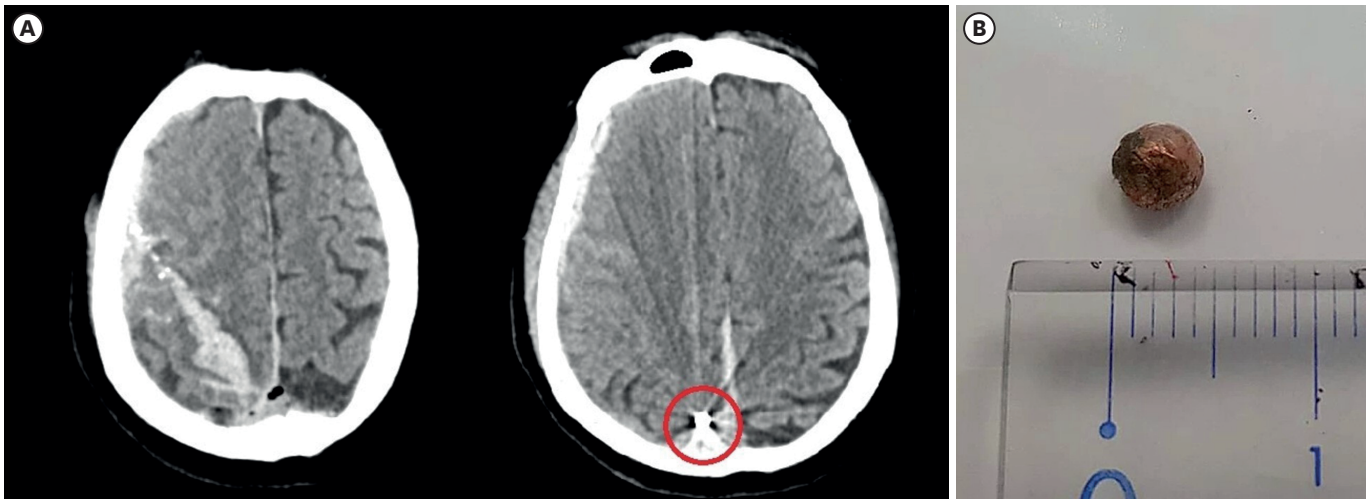

FIGURE 5. Illustrative case 5.
A 72-year-old male patient visited the emergency room with shotgun wounds to the abdomen and head. Brain computed tomography showed metallic foreign material (red circle) at the right posterior parietal lobe with elongated intracerebral hemorrhage. (A) A craniotomy was performed by a neurosurgeon. Confirming the location of the foreign body using ultrasound, the bullet was removed by approaching along the shortest trajectory. (B) The patient was treated in an intensive care unit and is receiving rehabilitation with cane-assisted ambulation.

metallic bar penetrating the brain from the left frontal lobe to the right orbit (**FIGURE 6B & C**). There was no major vessel injury, but the bar had passed through the midline of the brain, suggesting significant damage. The rebar was removed from the head, followed by bilateral decompressive craniectomy, although brain swelling persisted (**FIGURE 6D**). He expired on the 4th day of hospitalization.

Case 7

A 55-year-old male patient visited the ER after experiencing cardiac arrest after a penetrating ax injury to the head (**FIGURE 7A**). Brain CT showed penetration into the superior sagittal sinus, and the patient was unconscious (**FIGURE 7B**). Cardiopulmonary resuscitation (CPR) was performed with asystole, but the patient expired without resuscitation.

Case 8

A 48-year-old male patient visited the ER for rebar penetration into the left axilla at a construction site. On arrival, cardiac arrest occurred, and resuscitation was obtained after CPR. A brain CT scan showed diffuse traumatic subarachnoid hemorrhage as the rebar penetrated through the foramen magnum. (**FIGURE 8**) Emergency surgery comprised an incision in the neck, rebar removal, vessel ligation, and external ventricular drain insertion surgery. The intracranial pressure was extremely high. Despite bilateral craniectomy, the patient expired on the 6th day of hospitalization.

DISCUSSION

Korea is a country with very strict gun control, and gunshot wounds, the most common global cause of penetrating injuries, are relatively rare. Therefore, it is not common for surgeons to experience patients with penetrating injuries. In Korea, many such experiences have been published as case reports[6,9,11]; however, no research has been reported on the scale of the present study. Our results suggest that patient prognosis is determined by the location

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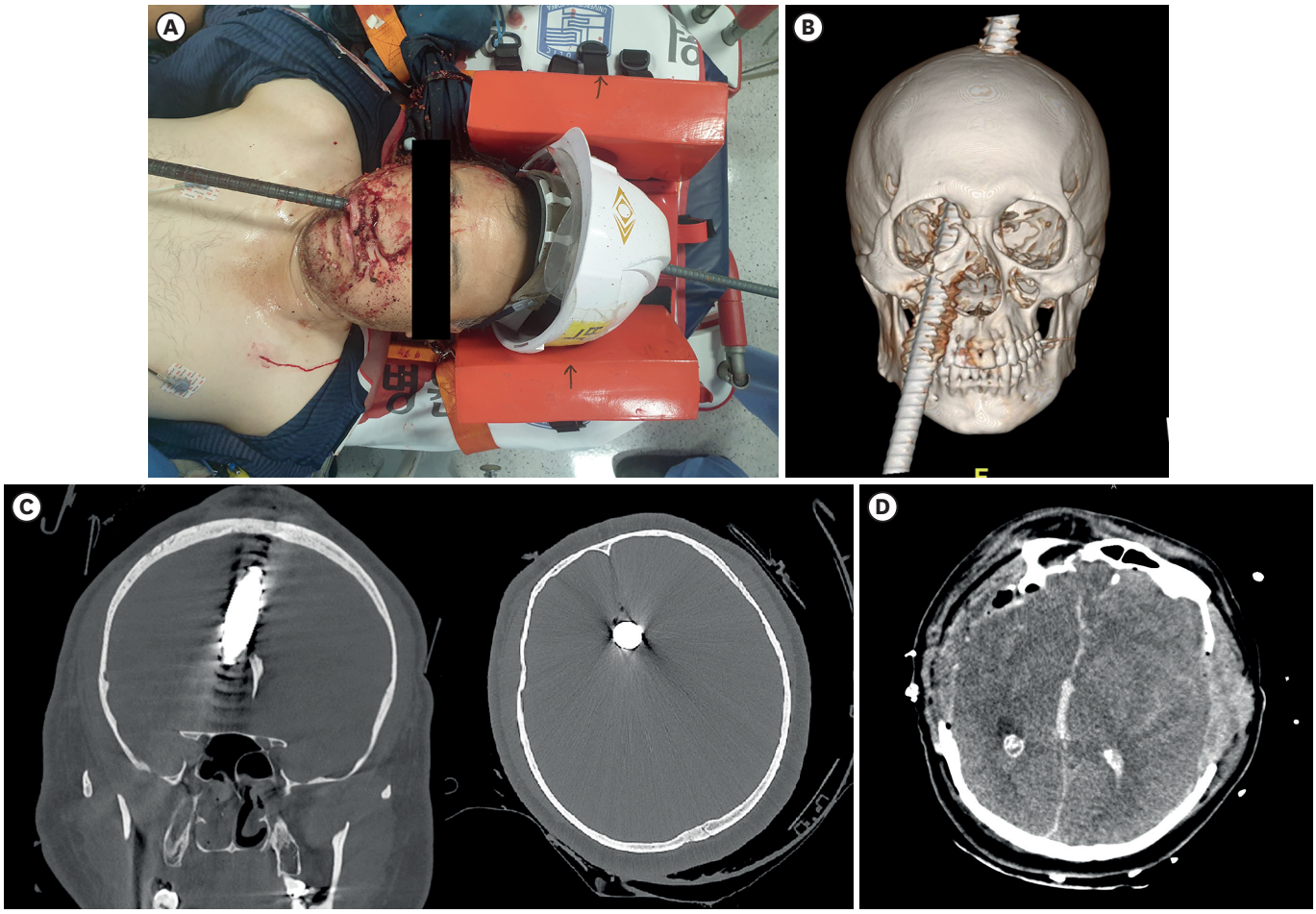

FIGURE 6. Illustrative case 6.
A 51-year-old male patient visited the emergency room after a 20-m rebar penetrated his hardhat and head. (A) On arrival, he was mentally drowsy and partially obeyed commands. Brain computed tomography showed diffuse cerebral hemispheric edema and penetration into the brain from the left frontal lobe to the right orbit. (B, C) The rebar was removed, followed by a bilateral decompressive craniectomy. (D) Despite this, brain swelling persisted, and he expired on the 4th day of hospitalization.

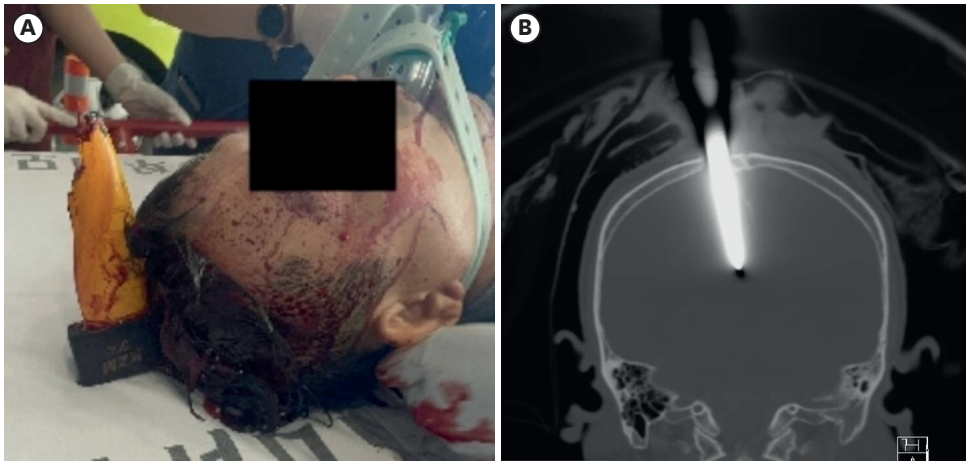

FIGURE 7. Illustrative case 7.
A 55-year-old male patient visited the emergency room with a penetrating ax injury. (A) On brain computed tomography, the ax was penetrating the superior sagittal sinus, and the patient was unconscious. (B) Cardiopulmonary resuscitation was performed with asystole, but the patient expired.

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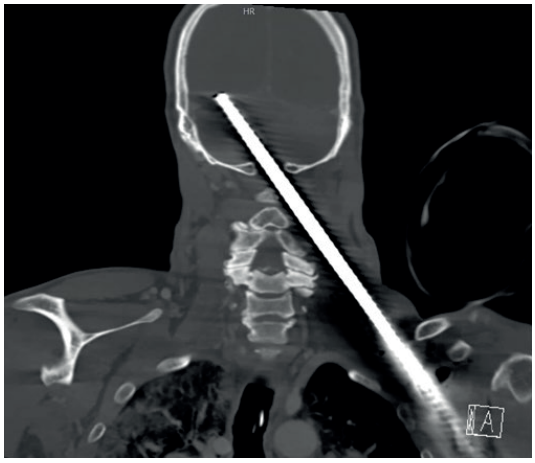

FIGURE 8. Illustrative case 8.
A 48-year-old male patient visited the emergency room with rebar penetrating the left axilla. The brain computed tomography scan showed diffuse traumatic subarachnoid hemorrhage due to penetration through the foramen magnum. Emergent external ventricular drain insertion surgery was performed. A bilateral craniectomy was performed for extremely high intracranial pressure, but he expired.

of the damage. If there is damage to the midline structure, which is directly related to life-sustaining functions, the prognosis is very poor. In this situation, even if actively treated, the survival rate is extremely low. On the other hand, damage to other parts of the brain is not necessarily life-threatening and might be treated through collaboration with other departments.

Knowledge in the fields of traumatology and traumatic brain injury (TBI) often is obtained on-site in situations such as war. Bullet and grenade shrapnel caused many penetrating brain injuries during World Wars I and II, and the traumatology of TBI developed when treating these patients.[15] Cushing first proposed a systematic classification of TBI into 10 groups[4] and introduced 4 essential surgical principles: 1) En bloc craniectomy at the site of penetration; 2) Detection and removal of bone fragments and damaged brain parenchyma along the wound track; 3) Incision of intact dura mater to remove blood clot and pulped brain; and 4) Distillation of dichloramine-T into head wounds after debridement. This treatment pathway reduced the mortality of penetrating missile wounds from 50%–60% to 28.8%.[3,5] Many injured patients with GCS scores greater than 8 or brain lesions limited to a single lobe of the brain can benefit from such early aggressive management.[10]

Several studies have been conducted on penetrating injuries, especially GSW, by surgeons in other countries. In a 5-year retrospective review of craniocerebral GSW, increasing survival was associated with aggressive resuscitation in all patients, and resuscitation with blood products or hyperosmolar fluids was independently associated with survival.[7] In construction-related cranial penetration injury, it is critical that the penetrating object not be removed at the construction site, during transport, or in the emergency center but under controlled conditions in the operating room.[1] Removal of such objects outside of a controlled environment could have serious consequences. Early active resuscitation is of great help for patient survival and is necessary to accurately identify the area and extent of damage through CT or CT angiography. Bell et al.[2] recommended digital subtraction angiography in the following situations: 1) Penetrating injury through the pterional/orbitofrontal region; 2) Known cerebral vessel injury with or without pseudoaneurysm on initial exploration; 3) Blast injury with GCS <8 (closed or penetrating); 4) Transcranial Doppler evidence of vasospasm;

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and 5) Spontaneous, unexplained decrease in partial pressure of brain oxygen. It is not always necessary to remove every foreign body such as bullet fragments as materials embedded in brain tissue do not migrate often and might not be easily accessible. As in Case 5 of the present study, if projectiles are easily accessed, they may be removed safely, especially with the assistance of a tool such as ultrasound for guidance. Clinical factors associated with poor outcomes following civilian craniocerebral gunshot wounds are GCS <5 (post-resuscitation) on admission, dilated and unreactive pupil, occipital entry wound, brainstem injury, injury to 'eloquent' brain, hypotension on admission, major intracranial vascular injury, and high intracranial pressure.[8,12,13] As with our current study, these previous studies have reported that patients with midline involvement, such as the brainstem, had a worse prognosis.

CONCLUSION

Penetrating injury of the orbitocranial region is critical and important in the field of neurosurgery. The greatest influences on patient prognosis are the area of damage and the level of consciousness, with GCS scores at the time of the visit. If the midline structure is damaged, the survival probability is extremely low. Further studies are needed to improve the survival of patients with midline orbitocranial injuries.

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