Transorbital penetrating injury: case series, review of the literature, and proposed management algorithm

Report of 4 cases

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Transorbital penetrating injury (TPI), an uncommon subset of head trauma, requires prompt multidisciplinary surgical intervention. While numerous case reports appear in the literature, there is a lack of discrete recommendations for initial evaluation, surgical intervention, and postoperative care of patients with TPI.

A retrospective review of 4 cases of TPI at the University of Michigan Health System was undertaken to assess for diagnosis, treatment, and follow-up. In addition, a PubMed search using the terms “penetrating orbital trauma,” “penetrating orbital injury,” “transorbital penetration,” and “transorbital penetrating injury” were used to search for articles discussing the presentation and management of penetrating orbital trauma.

All 4 of the patients at the University of Michigan underwent focused physical examination performed by a multidisciplinary trauma team followed by dedicated maxillofacial and head CT scanning. The patients’ treatments varied, depending on the mechanism and extent of the injury. An analysis of the case series presented here as well as other published cases suggests an algorithm for diagnosis and treatment for patients with TPI, which includes focused evaluation, diagnostic imaging with maxillofacial CT scanning, and management of the injury that focuses on the path of penetration and the presence of the foreign body in situ at the time of presentation. Magnetic resonance imaging is indicated in patients who have indwelling wooden foreign bodies. Angiography should be performed in patients with suspected vascular injury. Treatment decisions should be made by a multidisciplinary team with input from neurosurgery, ophthalmology, otolaryngology, and maxillofacial surgery.

Methods

We received approval from the University of Michigan investigational review board to collect pertinent data from the records of the 4 patients in our study. No informed consent was required, as this was a retrospective study detailing the hospital courses of each patient, with no identifying information presented. For the literature review, a detailed search of the MEDLINE PubMed database was performed on articles published between 1975 and 2009. Search terms included “penetrating orbital trauma,” “penetrating orbital injury,” “transorbital penetration,” and “transorbital penetrating injury.” From foreign body removal, the neurosurgical literature lacks a concise review of the literature that provides multidisciplinary treatment guidelines for transorbital penetrating injuries. The aim of this study is to present a series of 4 patients with penetrating orbital injuries by nonmissile projectiles from our institution and review the literature to provide a neurosurgical perspective regarding diagnosis, treatment, and follow-up in this patient population.

Key Words • wound • penetrating injury • foreign body • orbit • craniocerebral trauma • neurosurgical procedure • diagnostic imaging
the results of these searches, articles that included patient histories and/or diagnostic and therapeutic investigations were included in our review.

Case Reports

Case 1

Presentation and Examination. This 21-year-old restrained man fell asleep while driving and crashed his pickup truck into a tree, at which time the windshield wiper control indicator impaled his right cheek. On arrival to our emergency department, he complained of right cheek pain and loss of vision in his left eye. On physical examination, the indicator was found to be protruding from his right cheek (Fig. 1) and the patient was neurologically intact except for complete ophthalmoplegia in the left eye with a fixed and dilated left pupil. Maxillofacial and orbital CT scanning revealed that the indicator penetrated the inferolateral right maxillary sinus and traversed the nasal cavity and turbinates and the bilateral ethmoid sinuses to terminate in the superomedial left orbit (Fig. 2). There were associated comminuted fractures of those areas, as well as of the left orbital floor to the anterior margin of the inferior orbital fissure, the medial portion of the left orbital roof, and the cribiform plate. There was pneumocephalus present in the left frontotemporal extraaxial space and anteroinferolateral displacement of the left globe with an elongated appearance suggesting marked stretching of the left optic nerve.

Operation. The patient was started on high-dose intravenous methylprednisolone for optic nerve protection and taken urgently to the operating room for removal of the indicator jointly by members of the neurosurgery and otolaryngology teams. After placement of a lumbar drain, a bicoronal incision was made, and a frontal craniotomy with subcranial extension was performed, allowing for good exposure of the orbit and foreign body. The indicator was then removed under direct visualization, and multiple bone fragments were removed from the orbit and anterior skull base, including the cribiform plate. The anterior skull base was repaired by over-sewing the dura over the exposed olfactory nerves and placing a pericranial flap and split-thickness bone graft over the defect. The patient’s postoperative hospital course was uncomplicated.

Postoperative Course. The patient’s lumbar drain was removed on postoperative Day 8 and he was discharged home on postoperative Day 10. At follow-up visits, he continued to have no light perception in the left eye, but his ophthalmoplegia improved. Details of the ophthalmological and otolaryngological surgical techniques for this case have been previously reported.2,33

Case 2

Presentation and Examination. This 42-year-old man was operating a forklift when a cable attached to an industrial hook snapped, causing the hook to recoil and impale his left orbit. On arrival to our emergency department, the patient’s Glasgow Coma Scale score was 15, but he was amnestic to the details of the accident. He had a large steel hook firmly lodged in his left medial orbit between the globe and nose in the ethmoidal region causing left eye proptosis (Fig. 3). His right pupil was not reactive to light, and his left could not be assessed. He had no additional neurological deficits. A noncontrast head CT scan revealed that the hook extended from the left frontal sinus to the level of the hard palate and posteriorly into the sphenoid sinus. There were multiple displaced cranial fractures resulting in compromise of the right optic canal, as well as bony fragments lodged into the left frontal lobe (Fig. 4).

Operation. The patient was placed on high-dose steroids for optic nerve protection and prophylactic antibiotics. Because of the severity of his injury, he was taken to the operating room for removal of the hook under general anesthesia. A bicoronal incision and subfrontal craniotomy were performed, allowing good visualization of the portion of the hook penetrating the anterior cranial fossa. The hook was removed under direct visualization, and dural tears caused by bone fragments were repaired primarily or with vascularized pericranial graft. A right frontal ventriculostomy was placed, and debridement of the nasal cavity, ethmoid cavity, and orbital tissues commenced.

Postoperative Course. Postoperatively, the patient developed CSF rhinorrhea, which resolved after 10 days of CSF diversion via the ventriculostomy. The patient remained neurologically intact, except for absent vision in the right eye and 20/25 vision in his left eye, which persisted for the 18 months of follow-up.

Case 3

Presentation and Examination. This 21-year-old schizoaffective man with a history of multiple previous suicide attempts had attempted to commit suicide by forcing an ink pen through one orbit. Having failed to achieve
his goal, he then placed a second pen through his other
orbit. He was taken to a local hospital and then trans-
ferred to our institution. Physical examination revealed a
combative patient who required heavy sedation. The pa-
tient had no light perception bilaterally with bilateral or-
bital lacerations without definite puncture wounds visible.
Noncontrast maxillofacial CT scanning with sagittal and
.coronal reformatted images demonstrated tubular foreign
bodies oriented in the anteroposterior plane extending
from the orbital apices, through the medial aspects of
the superior orbital fissures, through the medial aspects
of the middle cranial fossa lateral to the sella, passing
just lateral to the pons bilaterally in the basilar cisterns,
and terminating in the most anterior aspects of the up-
per brachium pontis bilaterally where there was a small
amount of associated hemorrhage (Fig. 5). No other areas
of hemorrhage and no significant mass effect were pres-
ett.

Operation. The patient was taken to the operating
room for removal of the pens via bilateral transorbital ap-
proach jointly by members of the neurosurgery and oph-
thalmology departments. Two clear plastic pen casings
were withdrawn without difficulty, and no craniotomy
was performed.

Postoperative Course. The postoperative course was
uncomplicated. The patient remained nonreactive to light
bilaterally but was otherwise neurologically intact. He
was transferred to the psychiatry service 2 weeks after
his surgery.

Case 4

Presentation and Examination. This 5-year-old boy
was at a birthday party when, unwitnessed, he tripped
and fell forward, striking the right side of his face on the
handlebar of a bicycle. There was no observed loss of con-
sciousness or seizure activity. On arrival to our emergency
department, he was noted to be drowsy with marked right
periocular edema and proptosis of the right globe. Both

![Image](image-url)
pupils were equal and reactive; extraocular movements could not be assessed due to the patient not cooperating with the examination. Head and maxillofacial CT scans demonstrated comminuted fractures of the right orbital roof with depression of the fracture fragments into the right frontal lobe and associated intraparenchymal and subarachnoid hemorrhage and pneumocephalus (Fig. 6). There was also right proptosis with contusions involving the medial and superior rectus muscles, but no evidence of globe rupture.

**Operation.** The patient was admitted to the pediatric ICU unit for conservative management and observation and was placed on anticonvulsant therapy. The next morning, it was noted that he had a CSF leak from his right orbit, so he was brought to the operating room for repair of his skull base fractures and placement of a lumbar drain. A bicornoral incision was made, and a right frontal craniotomy was performed, allowing good exposure of the anterior cranial fossa. A fragment of bone was removed from the frontal lobe, and the dural tear was repaired primarily, as well as with a vascularized pericranial graft. The patient was taken back to the operating room the next day by the ophthalmology department for an eye examination, which revealed an approximately 1-cm corneal rust ring, a combination of metallic foreign body and its resultant immune cellular infiltrate.50

**Postoperative Course.** The remainder of the hospital stay was uneventful and the lumbar drain was removed on postoperative Day 2, the day before discharge. On follow-up 4 months after discharge from the hospital, the patient’s pupils were symmetric and reactive to light, with full range of extraocular motion. Of note, the only remaining deficit was a mild right ptosis.

**Discussion**

**Anatomy of the Orbit**

Shaped like a quadrilateral pyramid, the orbit directs penetrating objects to particular anatomical locations.
Objects will most often penetrate the roof of the orbit because of the angle of penetration (patients will often fall onto objects, as in our Case 4, directing the penetrating object at an upward angle) and because the frontal bone portion of the orbital roof is very thin. This often results in frontal lobe injury. The next most common path of injury is via the superior orbital fissure, as objects that enter the orbit at a low velocity are directed by the bony anatomy toward the superior orbital fissure. After an object penetrates through the superior orbital fissure, the bony structures direct it lateral to the cavernous sinus, beneath the frontal lobe, medial to the temporal lobe, above the petrous ridge, and lateral to the brainstem. Sometimes, however, the object can penetrate the cavernous sinus and/or the brainstem, potentially inflicting life-threatening injury. A third, rarer avenue of penetration is the optic canal, where the object is directed into the suprasellar cistern, close to the optic nerve and ICA.

**Diagnosis of TPI**

**Physical Examination.** Complete physical examination, including full neurological and ophthalmological examinations, is important in the diagnosis and appropriate treatment of any patient with penetrating orbital trauma (Fig. 7). Every patient, child or adult, with obvious ocular or palpebral injury should undergo full workup to rule out penetrating intracranial injury. Intracranial trauma cannot be excluded by a benign external appearance or an intact globe.

**Imaging.** Noncontrast maxillofacial CT scanning is the key imaging modality used when intracranial injury is suspected in an orbital trauma to determine the course of the object and the extent of bone and parenchymal injury. Some authors believe that a CT scan is not necessary in the case of a large metallic object due to the associated artifact, which may compromise imaging of key adjacent structures. However, we found in the case of orbital penetration by an industrial hook (Case 2) that noncontrast CT scanning was helpful in understanding the anatomical basis of our patient’s neurological deficits. Cranial radiographs may be useful in cases of penetrating injury by metallic foreign bodies to evaluate for intracranial penetration. Magnetic resonance imaging of the brain is useful in cases of wooden foreign body injury, as dry wood has a similar density as air and hydrated wood a density similar to soft tissue on CT scan, making diagnosis potentially difficult.

Cerebral angiography, or other less invasive modalities including CT angiography or MR angiography, is indicated when there is evidence of possible vascular injury, either by the location and trajectory of the foreign body or evidence of hematoma on CT scanning. When analyzing the trajectory of the foreign body on CT scanning, it is important to note whether the object traverses any areas of major vascular significance, including the ICA (especially within the cavernous sinus) and the anterior and middle cerebral arteries. If there is suspicion for vascular injury, angiography should also be performed to evaluate for traumatic aneurysm, which can develop soon after a penetrating injury. Other indications for early angiographic evaluation are fracture of the greater wing of the sphenoid and examination findings consistent with CN injury, both of which suggest possible injury to the middle cranial fossa or the cavernous sinus. We believe that the evidence, anecdotal though it is, supports the performance of cerebral angiography in such situations. The absence of angiography in Cases 3 and 4 of this report reflect the surgeon preference in these cases and should not be taken as recommendations for treatment in similar situations.

It is important to realize that the absence of focal neurological deficit may not always rule out the presence of a life-threatening intracranial injury, and one must have a high index of suspicion in such cases.

**Treatment of TPI**

As in any trauma, the basic tenets of advanced trauma life support must be followed in the case of penetrating orbital trauma. After stabilization, the penetrating foreign body can be assessed. Removal of the foreign body is deferred until after physical examination and full radiological evaluation. Premature removal of a penetrating foreign body outside of the controlled environment of the operating room may, in rare cases, lead to fatal hemorrhage.

Because of the unusual nature of transorbital injury, few data exist on the timing of the initiation and duration
of antibiotic therapy. However, based on the low risk of antibiotic therapy compared with consequences of CNS infection caused by the foreign body, we recommend initiation of antibiotic therapy on admission. If the foreign body is wooden, preoperative antibiotics appear to be particularly important, since the porous nature of wood is a strong growth medium for microorganisms. There are no data to support continuation of antibiotics after surgical removal. The value of culturing the removed foreign body is also undetermined, although it has been reported to be helpful when dealing with a wooden foreign body.

When treating any suspected CNS infection, antibiotic therapy should consist of broad-spectrum antibiotics with good CNS penetration, such as ceftriaxone, ciprofloxacin, and metronidazole. The use of high-dose

![Fig. 7. Schematic overview of the management of a patient who presented with a TPI. CTA = CT angiography; ICH = intracerebral hemorrhage; MRA = MR angiography.](image-url)
steroids to minimize damage to involved CNs remains controversial. In the setting of traumatic optic neuropathy, high-dose steroids decrease posttraumatic and postoperative edema, but an associated improvement in visual outcome has yet to be demonstrated. Some patients with TPI can be treated conservatively. Patients sustaining transorbital penetrating trauma by a sharp, streamlined metal object removed prior to arrival in the emergency department may be candidates for conservative management and often lack serious sequelae from their injuries. Similarly, patients who have sustained injuries that result in nondisplaced orbital fractures without bone fragments or evidence of retained foreign body may also be among those who are best suited to being managed conservatively.

The decision to operate on a patient with penetrating transorbital injury should be made as a collaborative effort between members of the neurosurgery, ophthalmology, otolaryngology, and maxillofacial surgery teams. Typically, the role of the neurosurgeon is to decompartment the brain and neurovascular structures, prevent injury to intracranial structures during removal, and assist in the reconstruction of the skull base. Subsequently the expertise of otolaryngologists and maxillofacial surgeons is needed to stabilize the orbital, maxillofacial, and rhinological structures.

Among the indications for surgical exposure following penetrating orbital injuries are retained foreign body, presence of dural defects (especially with CSF leakage immediately after trauma), displaced bone fractures, intracranial hematoma, and evidence of direct vascular injury. Some authors have suggested that emergency surgery is indicated in unstable patients with extended transorbital brain injuries in lieu of cerebral angiography to allow for prompt decompression and hemostasis. In cases in which the foreign body penetrates in or near the cavernous sinus, obtaining proximal and distal control of the carotid artery allows for safe removal of the object and vessel repair, if needed. Similarly, in cases in which the foreign body is near the cavernous sinus and there does not appear to be any parenchymal injury, control of the carotid artery can be obtained with temporary and/or permanent endovascular balloon occlusion, which would allow an externally accessible foreign body to be removed without craniotomy.

Traditionally, there have been 3 surgical approaches to remove a foreign body: frontotemporal craniotomy, subcranial craniotomy, and anterior orbitotomy. Frontotemporal and subcranial craniotomies can be accomplished with a bicornal incision and flap. Craniotomy is indicated when intracranial injury is suspected because it can allow for decompression of neural structures and adequate repair of bony and dural defects. A frontotemporal approach should be used when the injury is extensive and/or involves the middle fossa, and a wide exposure is necessary. The subcranial approach, which should be used for anterior fossa injuries caused by upwardly directed trauma requiring wide exposure, allows for less frontal lobe retraction and therefore a lower risk of parenchymal injury. Anterior orbitotomy can be used to repair orbital roof fractures if there is no evidence of vascular injury on CT scans because, compared with craniotomy, it is faster, less invasive, and has a shorter recovery time. Szabo et al reported a fourth approach to repairing injuries sustained from traumatic orbital roof fracture; the transpalpebral approach. This approach can be used in penetrating injuries that result in dural lacerations in the area of the orbital roof because it is minimally invasive and allows for shorter hospital stays and provides good cosmetic results.

The initial goals of surgery are decompression of neurovascular structures and removal of the foreign body under direct visualization. After the foreign body is removed, the operative goals shift to removal of bone fragments, repair of fractures, debridement of involved parenchyma, hemostasis, and dural closure. After surgical repair of intracranial injuries, the globe is evaluated extensively for injury. Postoperatively, CT scanning or MR imaging must be performed to rule out the presence of new/missed hematoma or retained foreign body.

In patients in whom there is no radiographic evidence of intracranial hemorrhage or damage to neurovascular structures, the penetrating object can be directly removed under general anesthesia, as was the case with our patient in Case 3. If the foreign body is thought to be tamponading bleeding but there is no evidence of vascular injury, some authors have removed the object under CT guidance, with a surgical team on standby in case a hemorrhage develops.

Complications After TPI

There are a number of possible complications after transorbital, intracranial penetration of a foreign body. The transorbital penetration itself can cause specific complications related to the path by which the foreign body exits the orbit. When the object passes through the superior orbital fissure, it can cause orbital apex syndrome, which involves injury to the oculomotor nerve (CN III), trochlear nerve (CN IV), abducens nerve (CN VI), ophthalmic branch of the trigeminal nerve (CN V1), and optic nerve (CN II), resulting in loss of vision and ophthalmoplegia. If the object penetrates the cavernous sinus, it can cause cavernous sinus syndrome, which can manifest similarly to orbital apex syndrome, with the addition of injury to the maxillary branch of the trigeminal nerve (CN V2) as well as the oculosympathetic fibers, resulting in facial numbness and miosis. As mentioned above, penetration through the orbital roof often results in frontal lobe contusions. A CSF leak can also occur due to the trauma, but if one is not initially evident, we do not recommend operating prophylactically to try to prevent one from developing. Prophylactic operation exposes the patient to the risks inherent to surgery, and a CSF leak can usually be managed conservatively.

Trauma to the globe can result in sympathetic ophthalmia, an autoimmune process resulting in bilateral, nonnecrotizing granulomatous uveitis. While the exact pathophysiology is not understood, it is believed that an autoimmune reaction develops in response to exposed ocular antigens after globe disruption. Since the development of sympathetic ophthalmia is a rare event and is delayed by up to 10 days following globe injury, encu-
ation can be performed at a separate sitting, allowing acute neurosurgical issues to be treated first.\(^6\)

Postoperative complications after repair of a penetrat-
ing orbital injury include CSF leak, meningitis, cerebral abscess, carotid cavernous fistula, traumatic aneurysm, and progressive intravascular thrombosis.\(^5,7\) Cerebrospi-
nal fluid leaks can initially be treated with CSF diversion via ventricular or lumbar catheter, but persistent leaks often require surgical treatment.\(^8\) When a patient develops a cerebral abscess postoperatively, a retained foreign body should be ruled out.\(^7\)

**Follow-Up of TPI**

In addition to clinical follow-up, all patients who have had penetrating transorbital injury should undergo follow-up outpatient maxillofacial CT scanning to ensure proper healing and to confirm the absence of a retained foreign body. Injuries that involve the region of the ICA should also be followed up using MR angiography or CT angiography 1–3 months after the injury to rule out the development of a pseudoaneurysm. In addition, patients who sustained their injury as a result of a suicide attempt may need inpatient psychiatric care and will need long-
term follow-up with a psychiatrist.\(^9,10,11\)

**Conclusions**

Transorbital penetrating injuries are uncommon, and their management is often complex. Removal of the foreign body outside the operating room is discouraged because of the possibility that it may be tamponading an injured vessel. It is imperative that preoperative imaging, including angiography if indicated, is obtained to assess for extent of injury and to assist in operative planning. A treatment plan for TPI should be determined by a multi-
disciplinary team, with input from neurosurgeons, otolar-
yngologists, and ophthalmologists.

**Disclosure**

The authors report no conflict of interest concerning the mate-
rials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Sagher. Acquisition of data: Schreckinger. Analysis and interpretation of data: Sagher, Orringer. Drafting the article: Sagher, Schreckinger, Orringer. Criti-
cally revising the article: Sagher, Orringer, La Marca, Thompson. Reviewed final version of the manuscript and approved it for submission: all authors. Study supervision: Sagher.

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Transorbital penetrating injury


Please include this information when citing this paper: published online September 24, 2010; DOI: 10.3171/2010.8.JNS10301

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