Wartime penetrating skull base trauma with unpredictable internal fragment ricochet and migration: illustrative case

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BACKGROUND Transnasal transsphenoidal penetrating craniocerebral injury is very rare even in wartime. Cases with good outcomes are even less common.

OBSERVATIONS A 20-year-old male sustained multiple fragment wounds to his head and face from a landmine explosion. One metal fragment entered his right nostril, traversed the nasal septum and anterior sphenoid sinus, and ricocheted superiorly off the clivus. The fragment then traveled almost to the surface of the left parietal lobe. Subsequently, under its own weight, it migrated back down its original track. The patient suffered cerebrospinal fluid rhinorrhea, pneumocephalus, and right-sided hemiparesis. Digital subtraction angiography was followed by microscopic transnasal skull base reconstruction supplemented by external lumbar drainage. Follow-up brain computed tomography showed further metallic fragment migration through the ventricular system. The fragment was removed through a transcortical approach. The patient's neurological examination and brain magnetic resonance imaging results demonstrated good recovery.

LESSONS The absence of external signs of deep injuries does not exclude the presence of a penetrating craniocerebral injury. Metal fragments may undergo ricochet and internal migration in both the brain parenchyma and the ventricular system. Timely diagnosis including three-dimensional reconstruction of a projectile’s trajectory may facilitate appropriate surgical planning in complex cases. Intraventricular fragment migration may necessitate microsurgical removal.

Penetrating craniocerebral injuries in which the projectile first passes through the sphenoid sinus and the sella turcica and then enters the brain are extremely rare.1-5 In our surgical series of 1288 patients with penetrating brain injuries (PBIs) operated on at Mechnikov Hospital, Dnipro, Ukraine, between February 24, 2022, and December 24, 2023, only two patients exhibited this type of projectile trajectory. In one patient, the shrapnel entered the nasal cavity through the medial orbital wall. This report describes the other case, in which a projectile entered the sphenoid sinus through the right nostril, causing only minor abrasions to the nasal ala.

Another complication of PBI is delayed migration of the projectile, which was reported in 4.2% of cases in the largest reported series of 213 patients who suffered a gunshot wound to the head.6-18 The timing of migration of intracranial bullets is quite variable and has been reported to occur within hours to days to as long as 4–5 years after injury. Most migrating projectiles are bullets, possibly related to their shape. Migration of other types of metallic fragments has been described only rarely. Several authors consider migration of a bullet or metal fragment through the ventricular system to be an indication for its removal.19-22 Fortunately, modern imaging technologies and surgical techniques make it possible to address these challenging problems successfully.23-27

Illustrative Case

A 20-year-old male patient sustained multiple shrapnel wounds to the head and face as a result of a landmine explosion (Fig. 1). He
had a brief loss of consciousness. Examination on admission revealed right-sided hemiparesis (arm strength 2/5, leg strength 3/3) and drainage of clear fluid from the left side of the nose, which was confirmed to be cerebrospinal fluid (CSF) after analysis for beta-2 transferrin.

The brain computed tomography (CT) revealed pneumocephalus, a metallic foreign body, and small intraparenchymal hemorrhages along the wounding projectile trajectory (Fig. 2). To analyze the projectile trajectory in more detail, bone window CT scans in the sagittal, frontal, and axial planes are shown, and CT reconstruction and three-dimensional (3D) modeling were performed (Fig. 3). Given the injury to the medial wall of the internal carotid artery (ICA) canal with the risk of vessel dissection, the patient underwent urgent digital subtraction angiography (DSA).

Surgical intervention was performed through a microsurgical transnasal transseptal approach (Leica M530 OHX microscope). During the approach, a nasal septum defect was verified. It was seen that the projectile had passed to the opposite side and pierced the anterior wall of the sphenoid sinus on the left.

Hematoma and bone fragments were removed from the left half of the sphenoid sinus, and the mucous membrane of the sphenoid sinus was removed. A bone defect was verified in the superior lateral parts of the sinus, from which CSF was leaking. The defect was closed using TachoSil (Corza Medical), and obliteration of the left half of the sinus was achieved with autologous fascia lata. To prevent displacement of the material used to close the defect, the entrance to the left half of the sinus was securely closed with bone fragments from the nasal septum and the anterior wall of the sinus, the nasal mucosa was returned to its anatomical position, and Merocel (Medtronic) nasal packs in the left half of the nose. External lumbar drainage was used for 5 days. Follow-up CT the day after the surgery showed that the metallic object had migrated posteriorly and laterally. The distance from the left posterior clinoid to the fragment on the initial CT was 1 cm, but on follow-up CT the distance was 3.6 cm. The distance from the fragment to the inner table of the left temporal bone changed from 3.9 cm on the initial CT scan to 3 cm on the follow-up CT scan. These findings gave us reason to believe that the fragment had migrated within the left lateral ventricle and thus would require microsurgical removal.

Immediately prior to surgery, a new brain CT scan was obtained with the head positioned as it would be during surgery (turned to the right). This was done to assess whether additional fragment migration had occurred. A middle temporal gyrus approach was chosen in order to provide the shortest path to the object while also avoiding the superior temporal gyrus of the dominant hemisphere. Figure 4 shows the immediate preoperative CT scan and the stages of the surgery.

The metal fragment was covered by a yellow-greenish soft film up to 2–3 mm thick. The metal fragment was loosely fused to the vascular plexus of the lower horn of the left lateral ventricle, which was possibly a consequence of inflammation that prevented its further migration through the ventricular system.

After extraction of the fragment from the brain, multiple small metal fragments were removed from the soft tissues of the head and face using a magnet. Six metal fragments were removed, ranging from 2 to 8 mm in the largest dimension. Removal of all metal fragments made possible a follow-up brain magnetic resonance imaging (MRI) (Fig. 5), which confirmed our understanding of the wounding projectile trajectory and the appropriate choice of microsurgical access for fragment removal.

From the moment of admission to the hospital, the patient was prescribed the antibiotics vancomycin and piperacillin-tazobactam for 10 days. Ventriculitis, meningocerebralitis, and other infectious complications did not occur.

The patient’s right arm and leg strength improved to a motor score of 4/5 within 3 weeks. There were no signs of CSF rhinorrhea. The patient was transferred to another medical facility for further neurorehabilitation.

**Patient Informed Consent**

The necessary patient informed consent was obtained in this study.

**Discussion**

**Observations**

Transnasal transsphenoidal penetrating shrapnel wounds are highly unusual injuries. The majority of traumas of this type are fatal on the battlefield. Survivors often have significant associated morbidities.

In a patient with sphenoid sinus injury, passage of a metal fragment with high kinetic energy through the seilia and parasellar area is likely to cause significant damage to critical neurovascular structures such as the ICA, cavernous sinus, and circle of Willis. Vascular injury has been reported in 10%–30% of patients with wartime traumatic brain injury, with aneurysms being the most common type of vascular injury.2 True aneurysm development in symptomatic patients with PBI has been shown to be rare.3 In our patient, DSA was urgently performed due to damage of the medial wall of the ICA canal, but even if the penetrating fragment does not directly injure vascular structures, early angiography in all PBI patients has been recommended for penetrating injuries associated with explosive blast, evidence of vasospasm, delayed neurological deterioration, or new intracranial hematoma.2

A projectile track through the sphenoid sinus also carries a high risk of infection and CSF leakage. One study reported infection rates in PBI to be 18% in surgically treated patients. The rate of CSF fistula formation was 12.8%, and in that group, 30% developed an infection.4 Our patient presented with CSF rhinorrhea and was treated with broad-spectrum antibiotics. He never showed signs of infection. We performed initial debridement of the missile track and repair of the CSF leak via a transnasal approach, similar to the procedures described by others,26–27 to which we added 3D modeling during presurgical planning. To guide decision-making about a transnasal endoscopic versus open craniotomy approach, Lee et al. suggested that an endoscopic approach should be considered only in patients without vascular injury or focal neurological deficits.26 These conditions were present in our patient.

Migration of intracranial bullets is an uncommon but well-recognized sequela of penetrating brain injury. Foreign body migration presents unique management challenges, the most important of which is deciding whether the object should be removed. Moores concluded...
FIG. 2. A–J: Axial brain CT scans show pneumocephalus in the right anterior temporal fossa and in the parasellar region (A and B). A metallic foreign body in the medial left temporal lobe (arrows) causes signal artifact (C–E); pneumocephalus is seen in the basal and anterior frontal region. Small intraparenchymal hemorrhages (arrowheads, F and G) along the trajectory of the projectile are seen in the medial parts of the left hemisphere. Pneumocephalus is visible in the terminal parts of the projectile’s path (arrows, H and I) in the postcentral gyrus. Along the convexity, the cerebral cortex and skull are intact, indicating the absence of ricochet from the calvaria (J).

K–R: Bone window axial CT scans show a fracture of the nasal septum (thick arrows, K and L) and the medial wall of the left ICA canal (thin arrows, M–O) as well as bone fragments in the left half of the sphenoid sinus. Small bone fragments (arrowheads, P–R) resulted from explosive fracture of the posterior clinoid on the left. The metallic projectile is also visible (R).

S–Y: Bone window sagittal CT scans (S–U) show a bone defect in the bottom of the sella (arrowheads). Pneumocephalus is present in the prepontine cistern (stars). Coronal views (V–Y) show a bone defect at the skull base and small bone fragments from the posterior clinoid on the left (arrows).
that migration did not usually change initial surgical management and  
that the fragment size and proximity to critical structures, including  
CSF outflow obstruction, should be used to determine the need for  
removal.\textsuperscript{12} There are many instances in the literature where a strategy of nonremoval has acceptable outcomes,\textsuperscript{7,16,17} but even though  
our patient did not have frank CSF obstruction, we felt that the position  
of the fragment within the lateral ventricle and its rapid migration  
mandated its removal. Aydoseli et al. described a case in which intra-  
ventricular bullet migration caused hydrocephalus weeks after initial  
presentation.\textsuperscript{20} Of note, we were able to access the fragment with  
minimal disruption of surrounding structures. Importantly, we obtained  
imaging after patient positioning to ensure that further migration had  
not occurred, a practice recommended in several reports that document  
fragment migration after changes in position.\textsuperscript{12,24}

**Lessons**

In this case, factors contributing to a favorable outcome included  
a detailed analysis of the trajectory of the projectile and its ricochet  
and migration, early transnasal and intracranial intervention, and anti-  
biotic therapy. Early cerebral angiography prior to skull base repair  
was essential to ensure that no underlying neurovascular injuries were  
present. CSF rhinorrhea was successfully treated using a transnasal
approach, and the migrating projectile was removed in a minimally invasive manner, thereby minimizing the likelihood of subsequent infectious complications and optimizing conditions for maximal functional recovery of the patient. Delay in detection, intervention, or repair may have led to fatal consequences. This is especially true in a combat casualty undergoing prolonged evacuation to a medical center remote from the front lines. Proximity, experience, and expertise close to the battle allowed early identification and treatment.

The decision to remove a foreign body is based on its type and size, its location, and the likelihood of developing further complications. Before planned surgical removal of an intracranial projectile, it may be prudent to obtain a radiograph just after final head positioning to verify that projectile migration has not occurred.

References


Disclosures
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