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CLINICAL ARTICLE

# Wartime penetrating sellar/parasellar injuries: a novel classification and management based on trajectory

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**OBJECTIVE** Penetrating brain injuries (PBIs) involving the sella region are rare, anatomically complex, and associated with high morbidity due to the proximity of critical neurovascular structures. Herein, the authors introduce a novel trajectory-based classification system derived from wartime injuries sustained during the conflict in Ukraine, aiming to improve the diagnostic framework, guide management strategies, and support prognostication in this unique population.

**METHODS** The authors conducted a retrospective analysis of all PBIs involving an anatomically defined critically important sellar injury zone (CRISIZ) treated at a tertiary care center over a 2.5-year period (February 2022–August 2024). Injuries were classified into 2 main categories based on projectile trajectory to the CRISIZ: transbasal (TB) and transcortical (TC). Each category was further subdivided into 4 anatomical subtypes. Clinical presentation, imaging characteristics, complications, treatment modalities, and outcomes were compared across subgroups. The primary outcome was the Glasgow Outcome Scale (GOS) score at 6 months.

**RESULTS** A total of 29 patients with PBIs involving the CRISIZ were identified (mean patient age 38 years). TB injuries were more common than TC by a factor of 1.6 (18 vs 11; 62.1% vs 37.9%). TB subtypes included transnasal, transorbital, transmaxillary, and infratemporal trajectories; TC subtypes included transfrontal, transtemporal, transventricular, and transoccipital. TB injuries had a higher prevalence of multiple projectile fragments (88.9% vs 45.5%, $p < 0.05$) and CSF rhinorrhea (66.7% vs 18.2%, $p < 0.05$). TC injuries were associated with significantly higher rates of intracranial vascular injury (81.8% vs 22.2%, $p < 0.01$), subarachnoid hemorrhage, intraventricular hemorrhage, and coma on admission (54.5% vs 11.1%, $p < 0.05$). Overall, in-hospital mortality was 10.3%, and 75.9% of patients achieved favorable outcomes (GOS scores > 3) at 6 months.

**CONCLUSIONS** Projectile trajectory is a critical determinant of injury pattern and clinical course in PBIs involving the CRISIZ. TC injuries are associated with a higher incidence of neurovascular complications, while TB injuries more commonly involve CSF leaks. Early identification and management of these complications are critical for optimizing outcomes. The proposed classification scheme provides a practical framework to guide evaluation and management in this high-risk patient population.

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**KEYWORDS** arteriovenous fistula; blast injury; carotid cavernous fistula; cerebrospinal fluid; dissection; pseudoaneurysm; sella turcica; skull base; sinus; penetrating injury; global surgery; trauma; traumatic brain injury

Patients sustaining severe traumatic brain injury during military operations represent a unique and challenging population. Head and neck injuries comprise approximately 16%–21% of battlefield trauma, with penetrating brain injuries (PBIs) accounting for a significant portion. While PBIs are less common in civilian settings, their occurrence in military contexts often involves high-velocity mechanisms that are particularly devastating and require neurosurgical intervention.[1] PBIs involving the skull base are a rare and unique subset of this cohort that is poorly characterized in the literature.

Over the past 2 decades, particularly during Operations

**ABBREVIATIONS** ACA = anterior cerebral artery; CCF = carotid cavernous fistula; CRISIZ = critically important sellar injury zone; DSA = digital subtraction angiography; GCS = Glasgow Coma Scale; GOS = Glasgow Outcome Scale; ICA = internal carotid artery; ISS = Injury Severity Score; IT = infratemporal; MDRCH = Mechnikov Dnipropetrovsk Regional Clinical Hospital; PBI = penetrating brain injury; SAH = subarachnoid hemorrhage; ST = sella turcica; TB = transbasal; TC = transcortical; TF = transfrontal; TM = transmaxillary; TN = transnasal; TO = transorbital; TT = transtemporal; TV = transventricular.

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Iraqi and Enduring Freedom, our understanding of the pathophysiology and management of battlefield trauma has evolved considerably.[2] Analysis of PBIs from these conflicts has revealed key predictors of poor outcome based on Glasgow Coma Scale (GCS) score, injury mechanism, Injury Severity Score (ISS), and radiographic evidence of herniation.[2] One study reported a mortality rate of 21% for such injuries.[3] These findings are echoed in recent data from the war in Ukraine, where a similar PBI cohort demonstrated a 20.7% mortality rate.[4] By contrast, civilian PBIs are associated with mortality rates as high as 67%.[5] Neurosurgical intervention, when appropriate, has been associated with improved survival. However, decisions regarding surgical management often hinge on the subjective assessment of salvageability by the treating neurosurgeon. The existing literature on PBIs remains limited, with few high-quality studies and significant risk of bias.[6]

Among PBIs, those involving the sella turcica (ST) region are exceptionally rare and poorly characterized. The ST is a saddle-shaped depression within the sphenoid bone that houses the pituitary gland and is surrounded by the cavernous sinus, major intracranial vasculature, and cranial nerves.[7,8] Currently, there is no established classification system to guide management or prognostication of PBIs involving the sellar region. Existing literature includes limited classification schemes for frontal bone[9] or sphenoid sinus injuries,[10] neither adequately addressing the unique anatomy or clinical implications of transsellar trajectories. Shuker reported a small series highlighting potential entry vectors for transfacial injuries involving the sphenoid sinus.[10]

To address this gap, we propose a novel classification system centered on the critically important sellar injury zone (CRISIZ), a defined anatomical area encompassing the ST, sphenoid sinus, and a 1-cm radius around the ST. This zone includes the sella and its contents as well as the parasellar area bounded by the cavernous sinus and its contents laterally, the clivus and dorsum sellae inferiorly, and the suprasellar area spanning from the diaphragma sellae to the third ventricle, which includes the stalk, optic apparatus, and circle of Willis. Because of its compact size and critical structures, injuries within this zone often carry a high risk of morbidity and mortality. Unfortunately, warfare continues to afflict multiple regions, including Ukraine, the Middle East, and Sudan. Therefore, we aimed to establish an informed classification of these injuries from modern warfare as we have established for posterior fossa injuries.[11] Incorporating projectile trajectory analysis into this framework enhances clinical relevance and offers a basis for treatment stratification and prognostication.[12]

# Methods

## Study Design

We conducted a retrospective cohort study of all patients with PBI admitted to a tertiary clinical center, Mechnikov Dnipropetrovsk Regional Clinical Hospital (MDRCH) in Dnipro, Ukraine, during a 30-month period (February 2022–August 2024). The study was approved by the hospital's ethics committee. All injuries were sustained during wartime and included military personnel and civilians. All patients underwent head CT and were diagnosed with a gunshot wound or mine blast PBI with projectile trajectory involving the CRISIZ.

## Study Variables

Data from the patient's medical records and discharge documentation from military or civilian hospitals were reviewed. Demographics, presenting symptoms, GCS score and ISS on admission, laboratory values on admission, injury characteristics, imaging characteristics based on CT findings, including Rotterdam scores[13] and projectile trajectory, operation types, operative parameters, perioperative outcomes, complications, and functional outcomes were recorded. To reduce bias, CT scans were reviewed (in each case, in brain and bone windows) by 2 specialists: a neuroradiologist and a neurosurgeon. Patients were categorized based on CRISIZ injury type: transcortical (TC) versus transbasal (TB). Follow-up for patients discharged alive from MDRCH was available. Long-term outcomes at 6 months were assessed using the Glasgow Outcome Scale (GOS).[14]

## Statistical Analysis

Statistical processing and data analysis were performed using STATISTICA version 10 (StatSoft Inc.). Descriptive analyses were performed on all variables under study, and the results are presented as frequency and/or mean with SD. The Student t-test was used for unrelated samples considering homogeneity variances (Fisher's test). Median and IQR were derived using the Mann-Whitney U-test for comparisons. The probability of differences in categorical variables was assessed by the 2-tailed Fisher exact test; $p < 0.05$ was considered statistically significant.

# Results

## Patient and Injury Characteristics

During the study period, there were 1498 recorded casualties with traumatic brain injuries, of whom 29 (1.9%) patients had PBI involving the CRISIZ. The 29 patients were all males aged 12–73 years (mean 38 ± 12.1 years). The majority were military personnel (n = 27; 93.1%). The GCS score ranged from 4 to 15 (median 12). The admission ISS score ranged from 16 to 75 (median 29). In addition to PBI, 22 (75.9%) patients had combined injuries of other organs and systems (Table 1).

The type of projectile was shrapnel from blast fragmentation in all patients. Fourteen (48.3%) patients had rhinorrhea, and 13 (44.8%) had neurovascular injuries on admission. In terms of CT findings, the most common included pneumocephalus (n = 23; 79.3%) followed by an intradural trajectory, subarachnoid hemorrhage (SAH), and intracerebral hemorrhage, each present in 21 (72.4%) patients (Table 1).

## Proposed Sellar/Parasellar Penetrating Injury Classification

A critical analysis of various types of injuries involving the CRISIZ allowed us to distinguish patients into 2 co-



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**TABLE 1. Patient injury characteristics, operative variables, and outcomes**

| Variable | Value |
|---|---|
| Military personnel | 27 (93.1) |
| Mean age, yrs | 38 ± 12.1 |
| Median GCS score | 12 (8, 13) |
| Median ISS | 29 (25, 36) |
| Concomitant injuries | 22 (75.9) |
| Maxillofacial | 12 (41.4) |
| Orbital | 6 (20.7) |
| Neck | 2 (6.9) |
| Thoracic | 6 (20.7) |
| Abdomen | 2 (6.9) |
| Limbs | 6 (20.7) |
| Soft tissue | 7 (24.1) |
| Type of projectile | |
| Gunshot wounds | 0 (0) |
| Shrapnel/blast fragmentation | 29 (100) |
| CSF rhinorrhea | 14 (48.3) |
| Intracranial vascular injury | 13 (44.8) |
| Intracranial CT findings | |
| Multiple fragments | 21 (72.4) |
| Ventricular involvement | 7 (24.1) |
| Intradural trajectory | 21 (72.4) |
| Intracerebral hemorrhage | 21 (72.4) |
| SAH | 21 (72.4) |
| Massive SAH (>1 mm in multiple cisterns) | 11 (37.9) |
| Intraventricular hemorrhage | 6 (20.7) |
| Pneumocephalus | 23 (79.3) |
| Tension pneumocephalus | 5 (17.2) |
| Basal cistern compression | 10 (34.5) |
| Midline shift >5mm | 8 (27.6) |
| DSA finding | 24 (82.8) |
| CCF | 3 (10.3) |
| Traumatic intracranial aneurysm | 3 (10.3) |
| Dural arteriovenous fistula | 3 (10.3) |
| Arterial occlusion | 2 (6.9) |
| Arterial transection | 2 (6.9) |
| Intervention | |
| Only endovascular | 4 (13.8) |
| Only surgical (transnasal or transcranial) | 16 (55.2) |
| Endovascular + surgical | 3 (10.3) |
| Skull base repair | 13 (44.8) |
| Transnasal | 4 (13.8) |
| Transcranial | 9 (31.0) |
| Lumbar drain | 5 (17.2) |
| Complications | |
| Meningoencephalitis | 4 (13.8) |
| Ventriculitis | 2 (6.9) |
| Brain abscess | 1 (3.4) |
| Surgical site infection | 1 (3.4) |
| Hydrocephalus | 2 (6.9) |
| Extracranial ICA injury | 1 (3.4) |
| External carotid artery injury | 1 (3.4) |
| Extracranial venous injury | 2 (6.9) |
| Ischemic stroke | 3 (10.3) |
| Trigeminal neuropathy | 1 (3.4) |
| Median LOS, days | 7 (3, 12) |
| In-hospital mortality | 3 (10.3) |
| Malignant cerebral edema | 1 (3.4) |
| Large-vessel transection | 2 (6.9) |
| Median GCS score at discharge | 15 (12, 15) |
| GOS score >3 at 6 mos | 22 (75.9) |
| TB injury | 18 (62.1) |
| TN | 3 (10.3) |
| TO | 3 (10.3) |
| TM | 8 (27.6) |
| IT | 4 (13.8) |
| TC injury | 11 (37.9) |
| TF | 2 (6.9) |
| TT | 5 (17.2) |
| TV | 4 (13.8) |
| Transoccipital | 0 (0) |

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**TABLE 1. Patient injury characteristics, operative variables, and outcomes**

LOS = length of stay.
Values are presented as the number of patients (%), mean ± SD, or median (IQR).

horts: TB (n = 18 [62.1%]) and TC (n = 11 [37.9%]). In TB injuries, the wounding projectile has a trajectory from the bottom up to the CRISIZ (from the base of the skull), and in TC injuries, the wounding projectile enters this zone from above (via brain parenchyma). Among TB injuries, 4 subtypes of injuries were distinguished: transnasal (TN), transorbital (TO), transmaxillary (TM), and infratemporal (IT). These injuries typically involve paranasal sinuses as previously described.[15] Among TC injuries of the sellar zone, 4 subtypes of wounds were distinguished: transfrontal (TF; anterior), transtemporal (TT; lateral), occipital (posterior), and transventricular (TV; superior) (Fig. 1).

In the TB group, the TB-TM subtype was the most common, involving 8 of 18 patients (44.4%) followed by the TB-IT subtype (4/18; 22.2%). In the TC group, the most common subtypes were transtemporal (TC-TT) (5/11; 45.5%) followed by transventricular (TC-TV) (4/11; 36.4%) injuries. There were no transoccipital subtype injuries in our cohort (Table 1).

## Interventions and Outcomes

Overall, 24 (82.8%) patients with sellar injuries underwent digital subtraction angiography (DSA) on admission. Twenty-three (79.3%) patients underwent intervention; 16



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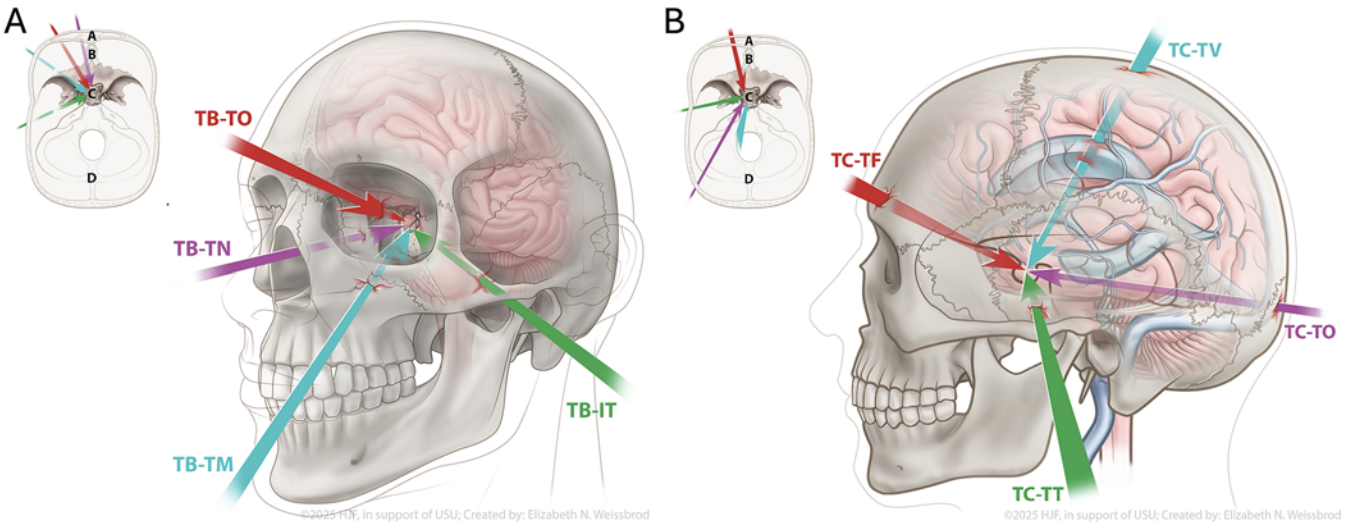



**FIG. 1.** Graphical representation of trajectories of penetrating injuries involving the CRISIZ and their trajectories. **A:** TB routes are demonstrated and include TB-TO, TB-TN, TB-TM, and TB-IT trajectories. **B:** TC routes are demonstrated and include TC-TF, TC-TT, TC-TV, and TC-transoccipital. **Insets** demonstrate axial views of trajectories in relation to the CRISIZ. Figure is available in color online only.

(55.2%) patients only had surgical intervention (transnasal or transcranial), and 4 (13.8%) patients had only endovascular interventions. Three (10.3%) patients underwent endovascular intervention followed by neurosurgical intervention, and 13 (44.8%) patients underwent repair and reconstruction of skull base defects for CSF rhinorrhea (9 via a transcranial approach and 4 via a transnasal approach) (Table 1).

Seven (24.1%) patients had infectious complications, and 3 (10.3%) patients had secondary ischemic strokes. The in-hospital mortality rate was 10.3% (n = 3). One patient with a TB injury died of hypothalamic-pituitary axis dysfunction and severe diencephalic injury, which caused critical fluid and electrolyte disorders. Two patients with TC injuries died of significant intracranial vessel injury, followed by large intracerebral hematomas and malignant intracranial hypertension (Table 1).

### TB Versus TC Injuries

There was a statistically significant difference between the groups regarding the severity of the patients' conditions assessed by the GCS, with significantly more patients having a GCS score < 8 in the TC group (54.5% vs 11.1%, p = 0.0281). CSF rhinorrhea was significantly more common in patients with TB injuries (66.7% vs 18.2%, p = 0.021). On imaging, Rotterdam scores were significantly higher in the TC group (median 3 vs 2, p = 0.017), with the TC group having more cases of intradural trajectory (100.0% vs 55.6%, p = 0.012), massive SAH (72.7% vs 16.7%, p = 0.005), intraventricular hemorrhage (45.5% vs 5.6%, p = 0.019), and midline shift (54.5% vs 11.1%, p = 0.028). Intracranial vascular injury was significantly more common in patients with TC injuries compared with those with TB injuries (81.8% vs 22.2%, p = 0.003) (Table 2).

There were no differences in intervention types or need for skull base repair between the two injury types. There were no significant differences in length of stay, complications, or functional outcomes at 3 or 6 months between the two injury types (Table 2).

## Illustrative Cases

### TB Injuries

#### TB-TN Injury

Three (10.3%) patients in our cohort had TB-TN injuries. One of these patients, a 39-year-old male, was admitted to MDRCH 23 hours after sustaining a mine blast injury, with a GCS score of 15. The shrapnel entered the right nasal wing and caused a right periorbital hematoma (Fig. 2A). Head CT indicated a wound canal through the right nostril with multiple fractures of the medial orbital wall, the medial maxillary sinus wall, bilateral fracture of the ethmoidal labyrinth cells, with multiple bone fragments in the nasal cavity, and multiple shrapnel fragments in the sphenoid sinus. The largest fragment ricocheted from the posterior wall of the clivus and lodged in the bony canal of the petrous internal carotid artery (ICA) (Fig. 2B and C). In addition, bilateral cerebral contusions with SAH were noted. DSA demonstrated traumatic occlusion of the right ICA (Fig. 2D), and embolization of the right ICA with coils was performed. Our rhinologist performed a transnasal debridement of the nasal cavity. No CSF leak, stroke, intradural injury, or delayed infection was noted. The cerebral contusions and SAH were managed conservatively. Another example of a patient with a TB-TN–type injury has been previously reported.[16]

#### TB-TO Injury

Three (10.3%) patients in our cohort sustained TB-TO injuries. A 40-year-old male sustained a mine blast fragment injury. He was transferred to MDRCH 9 hours after the injury, with a GCS score of 11T and combined chest and limb injuries. A 1-cm entrance wound to the right orbit



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**TABLE 2. Comparison of TB and TC sellar/parasellar injuries**

| Parameter | TB Injury, n = 18 | TC Injury, n = 11 | p Value* |
|---|---|---|---|
| Mean age, yrs | 36.9 ± 14.0 | 39.7 ± 8.5 | 0.558 |
| Median ISS | 27 (25, 36) | 29 (21, 54) | 0.856 |
| GCS score on admission ≤8 | 2 (11.1) | 6 (54.5) | 0.028 |
| Mean hematocrit on admission, % | 34.2 ± 5.3 | 35.0 ± 3.3 | 0.666 |
| Mean platelet on admission, $\times 10^9$/L | 227.0 ± 65.1 | 219.4 ± 88.5 | 0.791 |
| Mean glucose on admission, mmol/L | 5.9 ± 1.7 | 6.3 ± 2.5 | 0.334 |
| Mean WBC on admission, $\times 10^9$/L | 14.8 ± 5.3 | 18.4 ± 4.3 | 0.068 |
| Mean international normalized ratio | 1.1 ± 0.17 | 1.3 ± 0.5 | 0.359 |
| Mean fibrinogen, g/L | 3.0 ± 0.7 | 3.8 ± 2.1 | 0.255 |
| Median Rotterdam CT score | 2 (1, 2) | 3 (2, 3) | 0.017 |
| Median LOS | 8 (4, 14) | 4 (3, 12) | 0.211 |
| Median GCS score at discharge | 15 (12, 15) | 15 (12, 15) | 0.833 |
| Combined injuries | 14 (77.8) | 8 (72.7) | >0.99 |
| CSF rhinorrhea | 12 (66.7) | 2 (18.2) | 0.021 |
| Intracranial CT findings | | | |
| Multiple fragments | 16 (88.9) | 5 (45.5) | 0.028 |
| Intradural trajectory | 10 (55.6) | 11 (100.0) | 0.012 |
| Ventricular involvement | 2 (11.1) | 5 (45.5) | 0.071 |
| Intracerebral hemorrhage | 11 (61.1) | 10 (90.9) | 0.11 |
| SAH | 11 (61.1) | 10 (90.9) | 0.11 |
| Massive SAH, >1 mm in multiple cisterns | 3 (16.7) | 8 (72.7) | 0.005 |
| Intraventricular hemorrhage | 1 (5.6) | 5 (45.5) | 0.019 |
| Pneumocephalus | 12 (66.7) | 11 (100.0) | 0.058 |
| Tension pneumocephalus | 5 (27.8) | 0 (0.0) | 0.126 |
| Basal cistern compression | 4 (22.2) | 6 (54.5) | 0.114 |
| Midline shift >5 mm | 2 (11.1) | 6 (54.5) | 0.028 |
| DSA | 15 (83.3) | 9 (81.8) | 0.999 |
| Intracranial vascular injury | 4 (22.2) | 9 (81.8) | 0.003 |
| Open surgical intervention | 13 (72.2) | 10 (90.9) | 0.362 |
| Endovascular intervention | 3 (16.7) | 4 (36.4) | 0.375 |
| Skull base repair | 10 (55.6) | 3 (27.3) | 0.249 |
| Outcomes | | | |
| In-hospital mortality | 1 (5.6) | 2 (18.2) | 0.539 |
| Infectious complications | 4 (22.2) | 1 (9.1) | 0.622 |
| Ischemic stroke | 1 (5.6) | 2 (18.2) | 0.539 |
| Favorable outcome, GOS score >3 | | | |
| At 3 mos | 11 (61.1) | 5 (45.5) | 0.466 |
| At 6 mos | 15 (83.3) | 7 (63.6) | 0.375 |

WBC = white blood cell.
Values are presented as the number of patients (%), mean ± SD, or median (IQR) unless specified otherwise.
* Student 2-tailed t-test for continuous variables and Fisher's exact test for categorical variables.

with right periorbital hematoma was noted on examination (Fig. 2E). CT showed the wounding projectile trajectory through the lower wall of the right half of the frontal sinus and then the right orbit, causing linear fractures of the roof of the orbit, anterior cranial fossa around the ST, and clivus (Fig. 2F–H). Hemosinus of the frontal and sphenoid sinuses and bilateral brain contusions were noted. No signs of CSF rhinorrhea, infection, or vascular injury were observed. Given the depth of the metal fragment's bone penetration, we decided not to remove it. The patient underwent conservative treatment. The case of a similar patient with a TB-TO–type injury has been reported.[17]

### TB-TM Injury

The TB-TM injury type was the most common among TB injuries and occurred in 8 patients (27.6%), causing injury to the inferior ST. A 35-year-old male sustaining a combat-related mine blast fragment injury was brought



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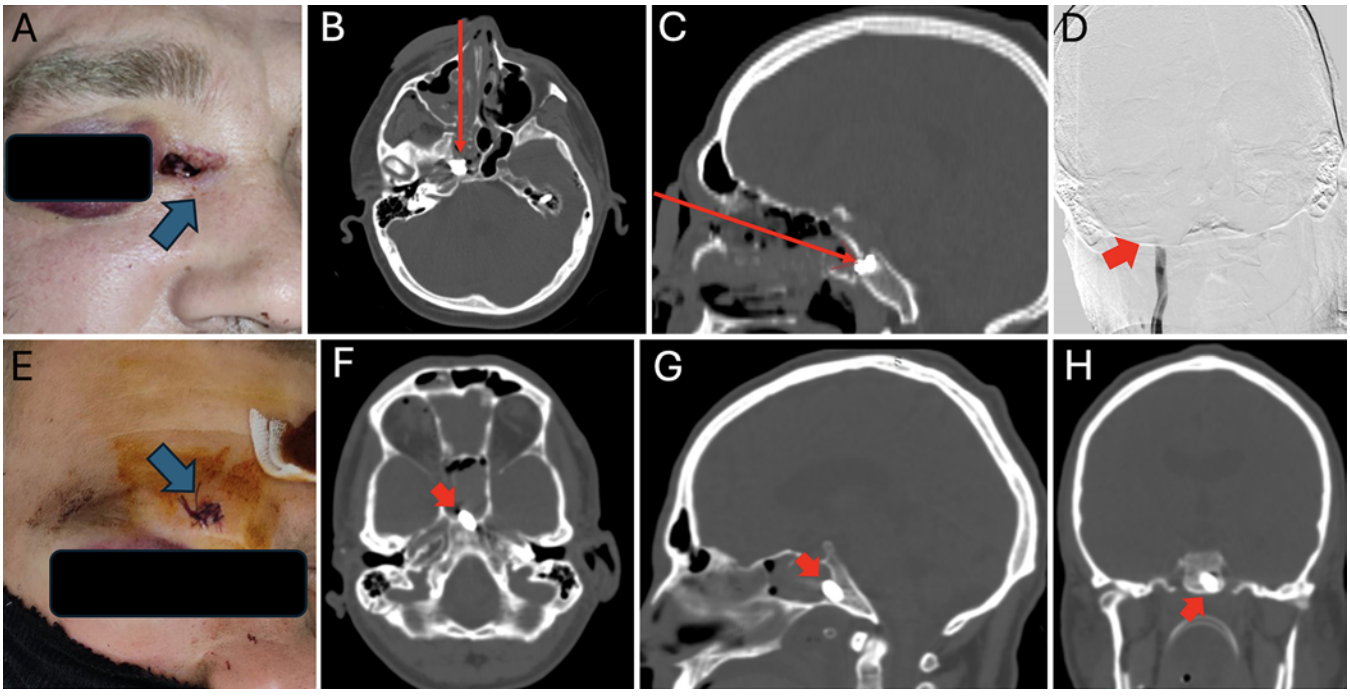



**FIG. 2. A–D:** Example of a TB-TN sellar injury. Entry site of shrapnel from the penetrating blast injury through the right nasal wing (A; *arrow*). Axial (B) and sagittal (C) bone window CT scans demonstrating multiple fractures of the medial orbital wall, the medial maxillary sinus wall, bilateral fracture of the ethmoidal labyrinth cells with multiple bone fragments in the nasal cavity, and large shrapnel fragment (1.4 × 1.2 × 0.9 cm) that ricocheted from the clivus and lodged in the petrous bone. The *red arrows* indicate the trajectory of the penetrating injury. Subtracted anteroposterior view of a right ICA injection demonstrating traumatic occlusion of the ICA (D; *arrow*). **E–H:** Example of a TB-TO injury. Entry site (*arrow*) of shrapnel from a penetrating blast injury through the right medial orbit (E). Axial (F), sagittal (G), and coronal (H) bone window CT scans demonstrating a 1.2 × 1.3 × 0.8–cm metal fragment (*red arrows*) passing through the right frontal sinus and right orbit, with fractures of the roof of the right orbit and the base of the anterior cranial fossa lodged in the clivus. Figure is available in color online only.

to MDRCH, with a GCS score of 15. Entry wound to the left maxilla with apparent CSF rhinorrhea was noted (Fig. 3A). Head CT demonstrated fracture of the anterior, posterior, and upper walls of the left maxillary sinus, with multiple metal fragments along the wound canal. A large cylindrical metal fragment (20 × 5 mm) perforated the bottom of the ST (Fig. 3B and C). Given the metal fragment location and the wounding projectile trajectory, DSA was performed to exclude neurovascular complications (Fig. 3D). No endocrinological abnormalities were noted. Thereafter, to repair the CSF leak and prevent infectious complications, a TN transsphenoidal surgical repair was performed in addition to left maxillary sinus debridement. A fibrin-collagen synthetic and a fragment of the fascia from the thigh were used to repair the defect. There were no complications, and the CSF rhinorrhea resolved.

### TB-IT Injury

Four (13.8%) patients in our cohort sustained TB-IT injuries. Given the wounding projectile trajectory, which is almost parallel to the skull base, these types of injuries can cause temporal lobe contusions. A 28-year-old male was brought to MDRCH, with a GCS score of 9 and profuse CSF rhinorrhea. CT demonstrated a metal fragment trajectory from right to left through the midline with destruction of the lateral walls of the sphenoid sinus and multiple skull base fractures and bilateral temporal contusions (Fig. 3E–H). Skull base reconstruction was undertaken using a TN transsphenoidal and TM approach with autogenous tissue and synthetic fibrin sealant. The patient required a decompressive hemicraniectomy on postoperative day 1 because of neurological decline to a GCS score of 7. His course was also complicated by meningoencephalitis that progressed to ventriculitis and communicating hydrocephalus despite antibiotics. After resolution of ventriculitis, a ventriculoperitoneal shunt was placed. His GOS score at 6 months was 3.

## TC Injuries

In TC injuries, the wounding projectile first penetrates the cranial vault, passes through the cerebral cortex, and then reaches the CRISIZ, making intracranial vessel injury a common occurrence in this type of injury. Additionally, as the wounding projectile moves, it loses kinetic energy and often lacks the energy to penetrate the skull base. This explains the low incidence of CSF leaks and need for skull base reconstruction in this injury type.

### TC-TF Injury

In the TC-TF type of injury, sustained by 2 patients in our cohort, the projectile typically passes through the frontal region of the head basally (usually through the frontal sinus) in the direction of the ST. The wounding projectile travels from top to bottom and front to back. This often re-



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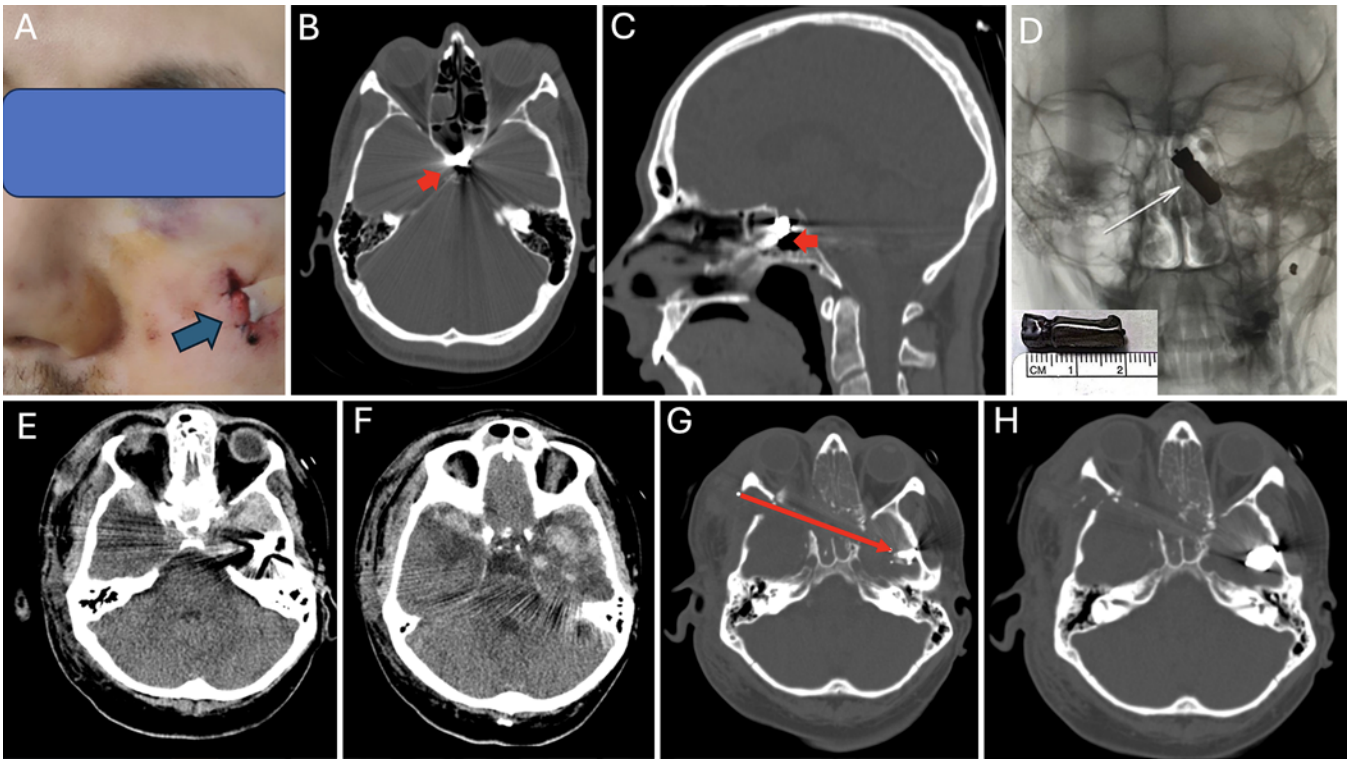



**FIG. 3. A–D:** Example of a TB-TM subtype injury. Penetrating injury from a mine blast with the entry wound to the left maxilla (*arrow*; A). Axial (B) and sagittal (C) CT scans demonstrating fractured walls of the maxillary sinus on the left, fragments along the wound canal, and a large cylindrical metal fragment (20 × 5 mm; *arrows*) traversing the sellar floor. Unsubtracted anteroposterior view of a left common carotid artery injection, demonstrating the proximity of the fragment (*white arrow*) to the cavernous ICA (D). **E–H:** Example of a TB-IT injury. Preoperative axial CT (E and F) and bone window (G and H) CT scans demonstrating a metal fragment with the trajectory from right to left through the midline (*arrow*; G) with destruction of the lateral walls of the sphenoid sinus and multiple skull base fractures. Figure is available in color online only.

sults in damage to the anterior cerebral artery (ACA) branches with the development of pseudoaneurysms.

A 49-year-old male presented with a penetrating entry wound to the head with a right frontal entry site. CT of the head demonstrated fracture through both walls of the frontal sinus, hypodensity of the right ACA territory, SAH, right frontal contusion, and a suprasellar metal fragment (Fig. 4A–C). The patient underwent DSA, which demonstrated a traumatic dissection and traumatic pseudoaneurysm of the right ACA at the A1–A2 junction (Fig. 4D). The pseudoaneurysm was successfully reconstructively occluded with coils with a patent parent artery. The patient subsequently underwent open surgical intervention for repair of the frontal sinus.

### TC-TT Injury

Five (17.2%) patients in our cohort had TC-TT injuries. In this type of injury, the wounding projectile passes through the temporal bone and parenchyma toward the direction of the CRISIZ. It can traverse the basal dura mater covering the cavernous sinus, or the greater wing of the sphenoid bone. In these types of injuries, direct carotid cavernous fistulas (CCFs) and dural arteriovenous fistulas have been diagnosed.

A 32-year-old male sustained multiple fragment head and neck injuries (Fig. 4E). He presented with a GCS score of 12 and left oculomotor nerve palsy. CT detected a left-sided temporal bone fracture from the entry injury and a right-sided foreign metallic parasellar fragment (Fig. 4F and G). Given the wounding projectile trajectory through the left cavernous sinus and the SAH, DSA was performed and demonstrated a direct CCF (Fig. 4H). The patient underwent endovascular deconstructive coiling of the left-sided direct traumatic CCF. The next stage was an open surgical intervention for the acute subdural hematoma, cerebral debridement of the left temporal lobe, and reconstruction of the middle cranial fossa with vascularized pericranial flap. The patient's condition improved, and no CSF leak or infectious complications were noted. In 2 other cases, after the high kinetic impact of wounding projectiles on the basal dura mater, traumatic dural arteriovenous fistulas developed.[18]

### TC-TV Injury

Four (13.8%) patients in the cohort sustained TC-TV injuries. The peculiarity of these injuries was that the entry point of the wounding projectile was on the convexity surface (frontal or parietal area) and the wounding projectile passed from top to bottom through the ventricular system in the direction of the CRISIZ.

A 31-year-old patient sustained a mine blast fragment injury during combat operations, with the entry site in the



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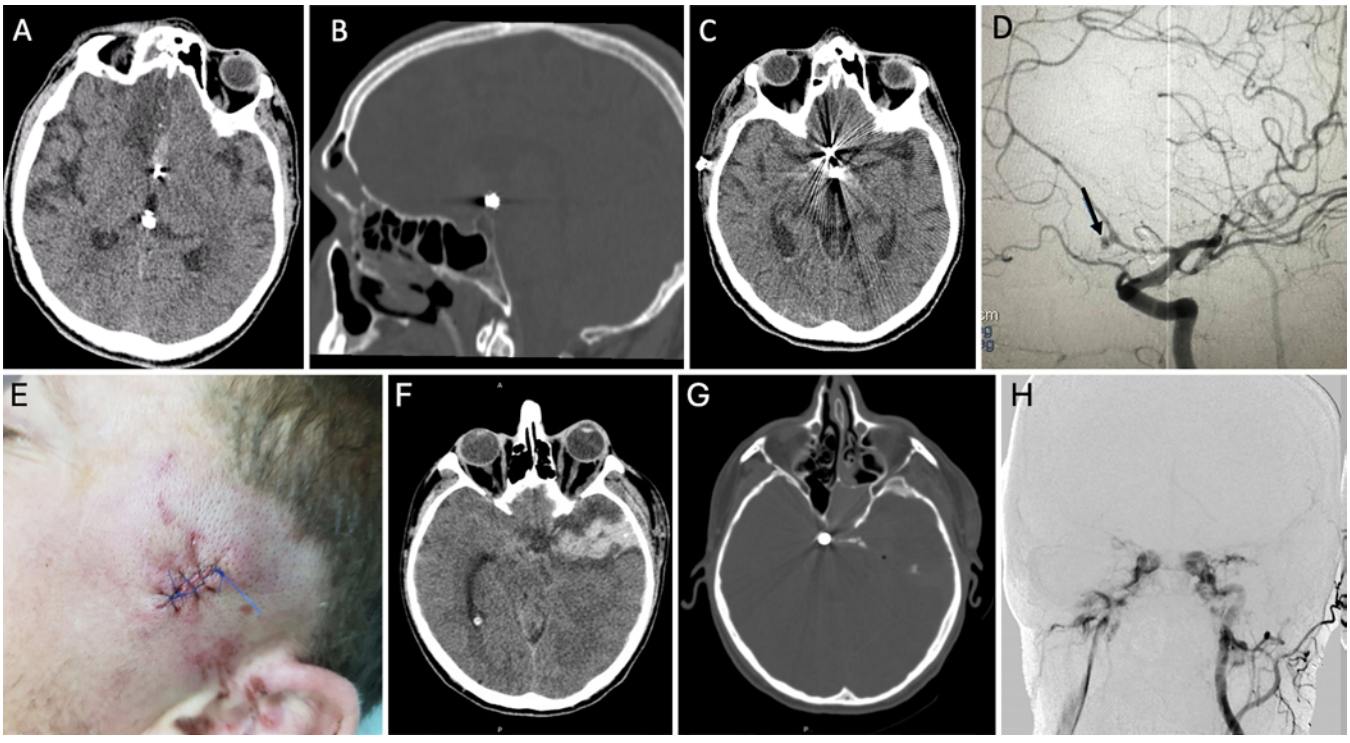



**FIG. 4. A–D:** Shrapnel blast injury to the head with a right frontal entry site causing a TC-TF injury. Axial head CT scans demonstrating fracture through both walls of the frontal sinus, hypodensity of the right ACA territory, SAH, right frontal contusion (A), and a metal fragment suprasellar near the circle of Willis (B). Axial CT scan obtained after intervention for sinus repair and reconstructive occlusion of the traumatic intracranial aneurysm (C). Oblique projection of the right ICA injection, demonstrating traumatic dissection and traumatic pseudoaneurysm of the right ACA at the A1–A2 junction (D; *arrow*). **E–H:** Example of a PBI causing a TC-TT injury. Left-sided 1 × 0.5–cm entry wound in the temporomandibular region (E). Axial CT scan showing an intracerebral hematoma and bone fragments in the left temporal lobe along the wound trajectory (F). Bone window CT scan demonstrating a metal fragment in the contralateral cavernous sinus (G). Left ICA injection demonstrating a direct traumatic CCF with early filling of bilateral cavernous sinuses and then into the superior ophthalmic veins bilaterally and pterygopalatine plexus (H). Figure is available in color online only.

left parietal region. The patient's ISS and GCS scores were 7T, respectively, on arrival. CT demonstrated intraventricular hemorrhage and a metal fragment location near the back of the ST (Fig. 5A–E). DSA was performed to exclude neurovascular complications (Fig. 5F), which was followed by primary surgical treatment of the penetrating craniocerebral injury, including removal of superficial bone fragments, evacuation of intracerebral hematoma, and cranioplasty. Because of the weight of the metal fragment and location, it caused a ventriculocisternostomy between the ventricular cavity and prepontine cistern. Thus, the patient developed no signs of hydrocephalus. Three months after the injury, the patient had moderate disability (GOS score 4), and examination revealed right hemiparesis.

Two patients with TC-TV injuries faced in-hospital mortality due to significant injury to large intracranial vessels with the development of large intracerebral hematomas and severe intracranial hypertension (Fig. 5G–I). Both underwent emergency decompressive craniectomies but did not survive.

## Discussion

The management of PBIs involving the sellar region remains a significant challenge due to the unique anatomical complexity of this area and the high morbidity associated with such injuries. Our study introduces a novel classification system for sellar injuries sustained during the Ukraine conflict, offering a systematic framework for assessing injury trajectory and outcomes.

By analyzing 29 cases, we identified distinct differences in the injury mechanisms, complications, and management between TB and TC injuries. This classification emphasizes the critical importance of the projectile trajectory in predicting neurovascular complications and CSF leakage, providing a foundation for more tailored approaches to diagnosis, surgical intervention, and long-term management. Knowledge of the features of TB and TC injuries in the CRISIZ allows the development of diagnostic and treatment algorithms/recommendations for these types of injuries. We observed that TC injuries are associated with higher likelihood of neurovascular injuries, more significant intracranial injury, and lower GCS scores on presentation, whereas TB injuries are associated with CSF leaks and the need for skull base repair endoscopically or transcranially. Therefore, in triaging these patients, we recommend DSA for all TC injuries as well as early surgical intervention for decompression and re-



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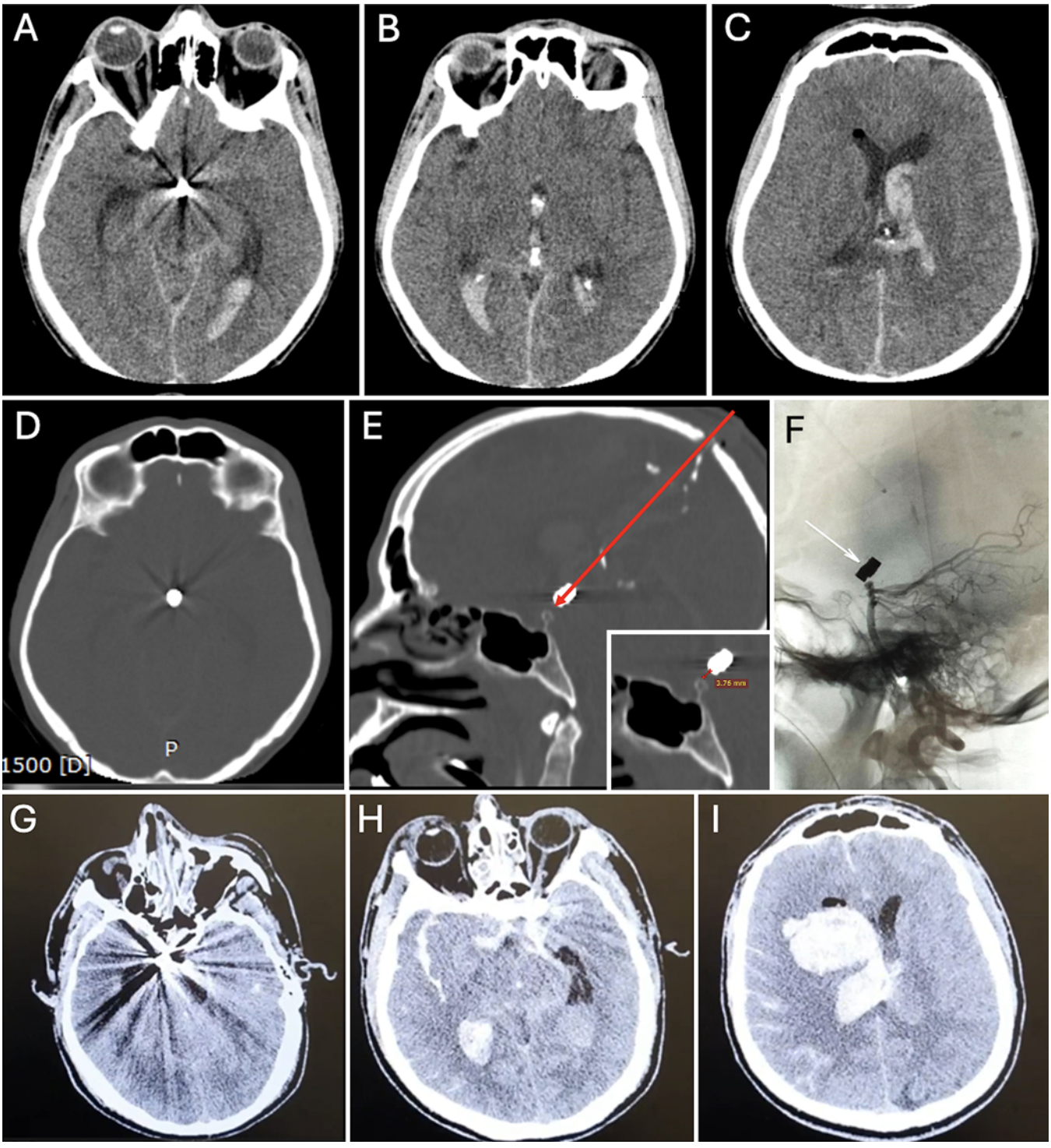



**FIG. 5.** Example of a TC-TV injury. **A–D:** Axial CT scans obtained in a patient who sustained a mine blast fragment injury from projectile entering the left parietal region, causing intraventricular hemorrhage, with the metal fragment 3.8 mm away from the sella. Sagittal CT scan demonstrating the trajectory of the projectile, which ends in the posterior sellar area (**E**; *arrow*). The **inset** demonstrates proximity to the dorsum sellae. Unsubtracted lateral view of a left vertebral artery injection, demonstrating proximity of the fragment (*arrow*) to the basilar tip and prepontine cistern (**F**). There were no intracranial vascular injuries. **G–I:** Axial CT scans obtained in another patient with a TC-TV injury with large shrapnel traversing the ventricles (G) and ending lateral to the sella with massive subarachnoid and intraventricular hemorrhages (H and I). The patient underwent decompressive craniectomy; however, the patient eventually died due to severe injury. Figure is available in color online only.



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**TABLE 3. Management approach and treatment considerations for patients with TB versus TC PBIs involving the CRISIZ**

| Injury Classification | TB | TC |
|---|---|---|
| Main risks of injury | CSF rhinorrhea | Intracranial vascular injury |
| Need for urgent intervention due to mass effect | Rarely | Often |
| Urgent diagnostic measures | High-resolution, thin-cut CT (w/ analysis of trajectory & involvement of paranasal sinuses) | DSA (CT angiography when DSA is not possible) |
| Approaches & preparation for intervention | Consider endoscopic, transnasal, or transorbital approaches | Consider endovascular intervention in hybrid operating room setting if available |
| Personnel & equipment considerations | Rhinology specialists | Cerebrovascular specialists |
| | Endoscopic equipment | Endovascular access |
| | Nasoseptal flap preparation | Blood transfusion products |
| | Allograft or synthetic sealant products | Proximal control |
| | Lumbar drain | Vessel graft preparation |

lief of mass effect from hematomas. On the other hand, for TB injuries, there should be low threshold for surgical repair of CSF leaks. Approaches such as transcranial or endonasal should be considered for skull base repair. Decision-making on fragment removal should be made on a case-by-case basis. Proposed considerations for treatment strategies between these two classes of CRISIZ injuries are presented in Table 3.

In a systematic review and meta-analysis of outcomes following combat-related PBIs, 12 studies with 1738 patients treated for PBIs in military settings were included and 64.3% underwent neurosurgical intervention.[19] Over a median follow-up of 9 months, 68.6% of patients achieved a favorable (GOS score > 3) outcome and 34.2% achieved a poor outcome. A GCS score > 8 at presentation was found to be an important predictor of a favorable GOS score and decreased mortality. The overall mortality was 18.0%. The pooled rates of CNS infection, seizures, and CSF leak/fistula were 13.8%, 13.2%, and 5.4%, respectively.[19] Similarly, in the civilian population, predictors of mortality in patients who have sustained PBI include a tram-track sign on CT scans, and also a trajectory through a particular supra–dorsum sellar transventricular zone was associated with fatal outcome.[12] PBI leads to high rates of cerebral arterial and venous injuries, and the projectile trajectory is emerging as an independent predictor of outcome.[20] Although there were no differences in outcomes between injury type to the CRISIZ, our overall good functional outcomes (GOS scores > 3) of 75.9% is similar to that in prior studies. Furthermore, the primary goal of our classification was not the prognostication or mortality prediction (like the zone fatalis[12] and SPIN [Surviving Penetrating Injury to the Brain] score[31]), but the prediction of complications: neurovascular and/or infectious ones and how to guide management of these injuries. In this regard, it is difficult to compare our anatomical classification with prognostic classifications.

In our prior cohort of PBIs, vascular injury was noted in 19.3% of the population.[18] In a large civilian cohort, vascular injuries were noted in as high as 60% of patients.[21] This difference is likely due to our low threshold to perform DSA in these patients. However, this also highlights the need for prompt vascular imaging or DSA to diagnose potentially life-threatening vascular injury. In addition to injury to intracranial vasculature, there is also increased risk of injury to extracranial vessels and external carotid artery branches, specifically in the TB type. These injuries might result in rare cases of severe epistaxis or extravasation into sinuses leading to significant blood loss. Injury to the cavernous ICA can lead to the development of a direct CCF.[22] Injury to intracranial segments of the ICA can cause significant intracerebral hematoma, increases in intracranial pressures, and death. Injuries to smaller diameter arteries (e.g., ACAs) can lead to pseudoaneurysms that should be diagnosed and managed early.[18,23]

Additionally, the removal of shrapnel fragments and bullets is something that needs to be taken into consideration in this population. Typically, fragments that require removal include those that are large, cause mass effect or neurovascular injury, and have migrated or are at risk for migration (ventricular location).[24,25] Fragments contained within the calvaria or skull base or without mass effect or at risk of migration can be left in place. Additionally, if the risk of removal outweighs any potential benefits, surgical removal is not warranted. When removal is necessary, fragments and foreign bodies in TB injuries can be removed via a transnasal approach.[26,27] In our series, removal of shrapnel fragments was performed in 38.9% (7/18) of TB injuries and 9.1% (1/11) of TC injuries ($p = 0.11$). Of the TB injuries, one fragment was removed via endonasal approach and the other 6 via an open transcranial approach. Indications for removal were large size, migration through the ventricular system, or location within the trajectory of approach of the operation.[16] In the majority of TC cases, fragments were left in place due to their small size and/or location requiring extensive surgical approach, which could lead to additional harm.

Another important consideration is the need to develop approaches and tactics for the treatment of penetrating craniocerebral injuries combined with intracranial vessel injury. Although clinical indicators such as anisocoria and imaging findings of massive hemorrhage were associated with poor prognosis in the 2 deaths in the TC cohort, there were shortcomings noted that could have altered management and outcome. First, both patients had intracranial vascular injuries that were not identified; DSA was not



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performed preoperatively. Thus, endovascular treatment was not considered in this situation. Second, the surgery was performed by neurosurgeons with no expertise in cerebrovascular matters and without proximal control. In the future, the management of these patients with complex neurotrauma in a neurovascular hybrid operating room might allow a rapid combination of traumatic vessel injury identification with DSA, consideration of endovascular intervention, and cerebral decompression and debridement in the same setting.[28,29]

### Limitations

This study has several limitations. First, it is based on a single-center experience during the Ukraine conflict, which could limit generalizability to civilian or noncombat PBIs. Despite being the largest cohort to date of CRISIZ injuries, the sample size remains small, restricting subgroup analysis. Additionally, follow-up beyond 6 months was incomplete, with 34.6% of patients lost to follow-up, limiting long-term outcome evaluation. Records beyond hospitalization remain limited and require significant investment of time and resources, especially during active warfare. As a result, we were unable to capture longer-term outcomes, such as functional recovery or delayed complications.

As in the legend of Abraham Wald and aircraft survivability,[30,31] survivorship bias exists within any trauma cohort, and more so in warfare trauma where mortality is high. Many individuals with more severe injuries might have died in the field or during evacuation, potentially skewing the dataset toward more survivable injuries. A more comprehensive analysis incorporating prehospital deaths would provide a better understanding of CRISIZ injury epidemiology.

Our proposed CRISIZ classification is anatomically informed but has not yet undergone external validation. Additionally, some injury patterns might fall outside our defined zones or involve overlapping territories, necessitating flexible application of this system. Lastly, the study's focus on wartime injuries introduces unique contextual factors, such as the nature of high-velocity projectiles and the resource-constrained environment, which might not directly apply to noncombat scenarios.

## Conclusions

PBIs to the sellar region are rare and complex. We propose a novel CRISIZ-based classification to guide management. Trajectory-based subtyping (TB vs TC) correlates with injury patterns, complications, and outcomes. Despite injury severity, favorable outcomes were achieved in most patients. While TC injuries were associated with higher rates of neurovascular complications, TB injuries showed a greater prevalence of CSF rhinorrhea. Early vascular imaging and tailored surgical intervention are critical for optimizing outcomes.

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## References

1. DuBose JJ, Barmparas G, Inaba K, et al. Isolated severe traumatic brain injuries sustained during combat operations: demographics, mortality outcomes, and lessons to be learned from contrasts to civilian counterparts. *J Trauma*. 2011;70(1):11-18.
2. Stevens JR, Brennan J. Management of battlefield injuries to the skull base. *J Neurol Surg B Skull Base*. 2016;77(5):430-438.
3. Larkin MB, Graves EKM, Boulter JH, et al. Two-year mortality and functional outcomes in combat-related penetrating brain injury: battlefield through rehabilitation. *Neurosurg Focus*. 2018;45(6):E4.
4. Sirko A, Pilipenko G, Romanukha D, Skrypnik A. Mortality and functional outcome predictors in combat-related penetrating brain injury treatment in a specialty civilian medical facility. *Mil Med*. 2020;185(5-6):e774-e780.
5. Aarabi B, Tofighi B, Kufera JA, et al. Predictors of outcome in civilian gunshot wounds to the head. *J Neurosurg*. 2014;120(5):1138-1146.
6. Loggini A, Vasenina VI, Mansour A, et al. Management of civilians with penetrating brain injury: a systematic review. *J Crit Care*. 2020;56:159-166.
7. Isman O, Kayar S, Murat Aktan A. Cone beam computed tomography evaluation of variations in the sella turcica in a Turkish population. *Folia Morphol (Warsz)*. 2020;79(1):46-50.
8. Emanuelli E, Zanotti C, Munari S, Baldovin M, Schiavo G, Denaro L. Sellar and parasellar lesions: multidisciplinary management. *Acta Otorhinolaryngol Ital*. 2021;41(Suppl. 1):S30-S41.
9. Garg RK, Afifi AM, Gassner J, et al. A novel classification of frontal bone fractures: the prognostic significance of vertical fracture trajectory and skull base extension. *J Plast Reconstr Aesthet Surg*. 2015;68(5):645-653.
10. Shuker ST. Management of penetrating war injuries: bullet/shell fragments in the sphenoid sinuses. *J Oral Maxillofac Surg*. 2008;66(10):2067-2072.
11. Sirko A, Traylor JI, Hicks WH, Yadav G, Armonda RA, Valadka AB. Surgical treatment of penetrating wounds after resuscitation study: a new classification system for penetrating injuries to the posterior fossa. *J Neurosurg*. 2025;143(2):443-449.
12. Kim KA, Wang MY, McNatt SA, et al. Vector analysis correlating bullet trajectory to outcome after civilian through-and-through gunshot wound to the head: using imaging cues to predict fatal outcome. *Neurosurgery*. 2005;57(4):737-747.
13. Maas AIR, Hukkelhoven CWPM, Marshall LF, Steyerberg EW. Prediction of outcome in traumatic brain injury with computed tomographic characteristics: a comparison between the computed tomographic classification and combinations of computed tomographic predictors. *Neurosurgery*. 2005;57(6):1173-1182.
14. Jennett B, Bond M. Assessment of outcome after severe brain damage. *Lancet*. 1975;1(7905):480-484.
15. Sirko A, Berlin C, Tsang S, Naik BI, Armonda R. Wartime penetrating traumatic brain injury of the anterior skull base involving the paranasal sinuses: a single-center, first-year experience from Dnipro, Ukraine. *J Neurosurg*. 2024;142(3):829-838.
16. Sirko A, Valadka A, Armonda R, Dragun AJ, Cherednychenko Y. Wartime penetrating skull base trauma with unpredictable internal fragment ricochet and migration: illustrative case. *J Neurosurg Case Lessons*. 2024;8(2):CASE24128.
17. Sirko A, Pelcher I, Dowlati E, Malyi R, Armonda RA. Microscopic endonasal transsphenoidal approach for repair



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of sellar defect from penetrating trauma during wartime: illustrative case. *J Neurosurg Case Lessons*. 2025;9(13): CASE24875.
18. Sirko A, Cherednychenko Y, Dowlati E, Armonda RA. Early multimodal neurointerventional and neurosurgical management of penetrating craniocerebral injuries: wartime experience from Ukraine. *J Neurosurg*. 2025;143(2):431-442.
19. Karras CL, Texakalidis P, Nie JZ, et al. Outcomes following penetrating brain injuries in military settings: a systematic review and meta-analysis. *World Neurosurg*. 2022;166:39-48.
20. Lazaridis C, Mansour A, Alvarado-Dyer R, et al. Civilian firearm-inflicted brain injury: coagulopathy, vascular injuries, and triage. *Curr Neurol Neurosci Rep*. 2021;21(9):47.
21. Mansour A, Loggini A, El Ammar F, et al. Cerebrovascular complications in early survivors of civilian penetrating brain injury. *Neurocrit Care*. 2021;34(3):918-926.
22. Loggini A, Kass-Hout T, Awad IA, et al. Case report: management of traumatic carotid-cavernous fistulas in the acute setting of penetrating brain injury. *Front Neurol*. 2021;12: 715955.
23. Serra R, Wilhelmy B, Chen C, et al. Acute development of traumatic intracranial aneurysms after civilian gunshot wounds to the head. *J Neurotrauma*. 2024;41(15-16):1871-1882.
24. Darwazeh R, Darwazeh M, Sbeih I, Yan Y, Wang J, Sun X. Traumatic brain injury caused by missile wounds in the north of Palestine: a single institution's experience with 520 consecutive civilian patients. *World Neurosurg*. 2018;116: e329-e339.
25. Aydoseli A, Unal TC, Aras Y, Sabanci PA, Altunrende E, Izgi N. Endoscopic removal of a bullet that migrated to the third ventricle causing hydrocephalus. *World Neurosurg*. 2017;105:1038.e11-1038.e16.
26. Verhaeghe W, Schepers S, Sun Y, et al. Removal of a low-velocity projectile from the base of the sphenoid sinus using navigation-guided endoscopy. *J Craniofac Surg*. 2012;23(2): 472-476.
27. Yıldırım AE, Divanlıoğlu D, Çetinalp NE, Ekici I, Dalgıç A, Belen AD. Endoscopic endonasal removal of a sphenoidal sinus foreign body extending into the intracranial space. *Ulus Travma Acil Cerrahi Derg*. 2014;20(2):139-142.
28. Fandino J, Taussky P, Marbacher S, et al. The concept of a hybrid operating room: applications in cerebrovascular surgery. *Acta Neurochir Suppl*. 2013;115:113-117.
29. Mueller K, Felbaum D, Bell R, Armonda R. The hybrid operating room. In: Spiotta AM, Turner RD, Chaudry MI, Turk AS, eds. *Management of Cerebrovascular Disorders: A Comprehensive, Multidisciplinary Approach*. Springer International Publishing; 2019:47-56. doi:10.1007/978-3-319-99016-3_4
30. Wallis WA. The Statistical Research Group, 1942–1945. *J Amer Stat Assoc*. 1980;75(370):320-330.
31. Mangel M, Samaniego FJ. Abraham Wald's work on aircraft survivability. *J Amer Stat Assoc*. 1984;79(386):259-267.
32. Muehlschlegel S, Ayturk D, Ahlawat A, et al. Predicting survival after acute civilian penetrating brain injuries: the SPIN score. *Neurology*. 2016;87(21):2244-2253.

## Disclosures

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

## Author Contributions

Conception and design: Sirko, Armonda. Acquisition of data: Sirko, Perepelytsia. Analysis and interpretation of data: all authors. Drafting the article: Dowlati, Sirko, Perepelytsia. Critically revising the article: Dowlati, Sirko, Armonda. Reviewed submitted version of manuscript: Armonda. Approved the final version of the manuscript on behalf of all authors: Dowlati. Statistical analysis: Sirko, Perepelytsia. Administrative/technical/material support: Armonda. Study supervision: Sirko.

## Supplemental Information

### Previous Presentations

Portions of this work were presented at the annual meeting of the European Association of Neurosurgical Societies (EANS2025), Vienna, Austria, October 5–9, 2025.

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