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Rupture of the Superior Sagittal Sinus in Penetrating Head Injury—Management of a Rare Trauma Mechanism

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Abstract

Civilian penetrating head injury caused by foreign objects is rare in Germany (Europe), but can result in complex neurovascular damage. We report on a patient who in suicidal intent inflicted on himself a penetrating brain injury near the vertex with a captive bolt gun. A laceration at the junction of the middle to the posterior third of the superior sinus occurred by bolt and bone fragments leading to critical stenosis and subsequent thrombosis. Upon surgery, the proximal and distal sinus openings were completely thrombosed. The sinus laceration was closed by suture and the intraparenchymal bone fragments were retrieved. Postoperative angiography disclosed persistent occlusion of the superior sagittal sinus. The patient did not develop any symptoms due to venous congestion (edema, hemorrhage), suggesting sufficient collateral venous outflow. The patient completely recovered despite the complexity of the lesion.

Keywords
- ► penetrating head injury
- ► superior sagittal sinus
- ► penetrating brain injury
- ► fractures

History

We report on a 56-year-old male Caucasian found at home with a Glasgow coma score of 9. The mid-sized pupils showed direct and indirect reaction to light; he was in a stable cardiopulmonary condition with regular spontaneous breathing. A strong bleeding from a thumb-sized parietal scalp wound was observed. Next to the patient, a captive bolt gun was found as used for slaughter. However, upon inspection, no foreign object was found on the exterior of the patient's head. The patient was sedated and intubated on site. The estimated duration between the time of trauma and the arrival of the emergency team was 15 minutes.

Trauma Mechanism

Captive bolt guns fire a bolt several centimeters into the head and brain of an animal using the pressure of a gas cartridge. The induced trauma causes unconsciousness and coma, but does not lead to immediate death of the animal.[1] Since the bolt retracts after penetrating the head, no projectile is retained intracranially.[2] In the present case, the patient placed the captive bolt gun onto the vertex of his head in the high parietal region. To increase the effect, he placed a 1 cent coin between his head and the gun. During the bolt release, the coin was driven intracranially by the bolt.

Radiological Examinations

Cranial incremental computed tomography (CCT) showed a mediosagittal parietal gunshot lesion with several bone fragments located in the parietal white matter. An additional round-shaped metallic structure could also be identified at a depth of around 5 cm (►**Fig. 1**). Accompanying discrete pneumocephalus, localized subarachnoid hemorrhage, and

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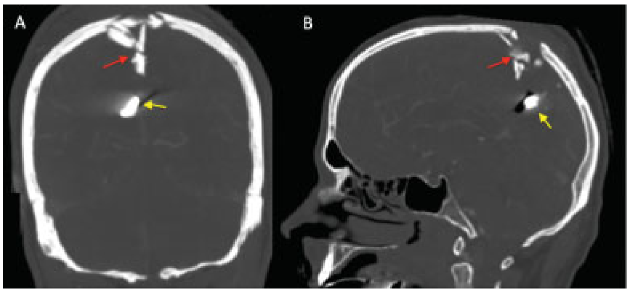

Fig. 1 Cranial computed tomography (CCT) with coronal (**A**) and sagittal (**B**) cuts, bone window: impression fracture with intracranial bone fragments (*red arrow*) and metallic foreign object (*yellow arrow*).

parenchymal contusions were also noted. However, no space-occupying intracerebral hemorrhage was found. Since the impression site was very close to the superior sagittal sinus (SSS), we suspected an occlusion of the sinus lumen by bony fragments. Nevertheless, brain edema or hemorrhage due to venous congestion was not present. Computed tomography (CT) angiography (CTA) ruled out arterial lesions (e.g., pericallosal artery), but confirmed SSS thrombosis with an empty delta sign posterior to the sinus lesion. The rostral part of the sinus was contrasted, however, suggestive of persistent regular blood flow, and bridging veins were dilated (►**Fig. 2**). Both examinations (CCT and CTA) were performed within 10 minutes of the patient's arrival at the trauma center.

Surgical Technique

Surgery was performed immediately following radiological examinations on the day of the trauma.

The patient was placed prone on the operating table with the head fixed in a Mayfield clamp. A horse-shoe incision was made with the missile entry point in the center. Burr holes were placed bilaterally to the SSS rostrally and dorsally to the bony gap. The craniotomy thus crossed the

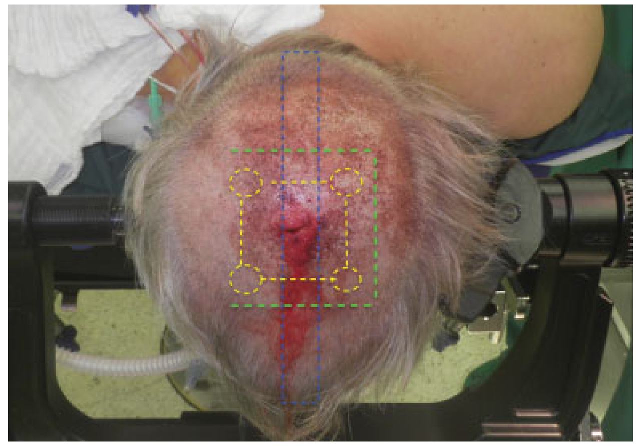

Fig. 3 Bullet entry point in the high parietal region (prone position, head positioned in a Mayfield clamp). Skin incision (*green*), burr hole placement and extent of craniotomy (*yellow*), and location of sagittal sinus (*blue*).

SSS (►**Fig. 3**). Elevating the bone flap, dislodged bone fragments were retrieved using rongeurs, exposing the underlying parietal cortex. The SSS was ruptured spanning 3 cm total length. Since the sinus orifice was thrombosed rostrally and dorsally, no major hemorrhage occurred from the sinus. Ligating sutures were placed on both orifices and fibrin glue was applied locally. Using the microscope, additional bone fragments could then be retrieved from the left parietal white matter in line with the intrusion vector. At a depth of around 5 cm the metallic fragment was located and removed, identifying it as a 1 cent coin (►**Fig. 4**). The resection vault was irrigated and covered with a hemostatic gauze (Tabotamp). A water-tight closure of the dura was performed using a small patch covering the lacerated SSS. Reconstruction of the calvaria was postponed, since the removed bone parts were suspected to be infected. The affected skin was debrided and sutured. A 7-day prophylactic antibiotic medication was initiated. The operative blood loss was 800 mL.

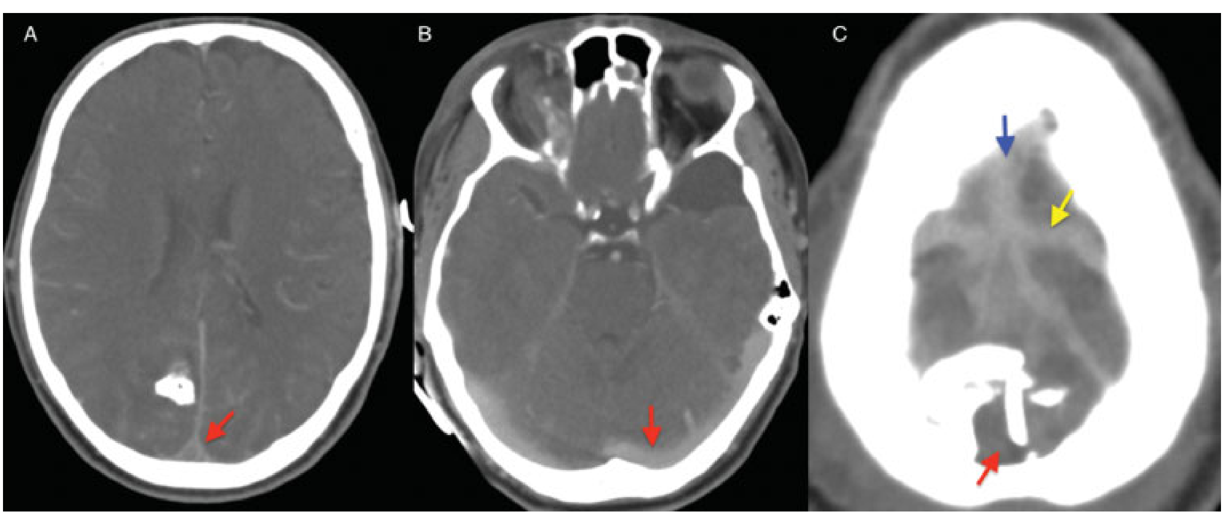

Fig. 2 Preoperative axial computed tomography angiography (CTA). (**A**) "Empty delta sign" indicating Thrombosed sinus segment (*red arrow*). (**B**) Transverse sinus shows regular flow from collateral feeding veins. (**C**) Regular flow through rostral (*blue arrow*) and distal sinus segments (*red arrow*).

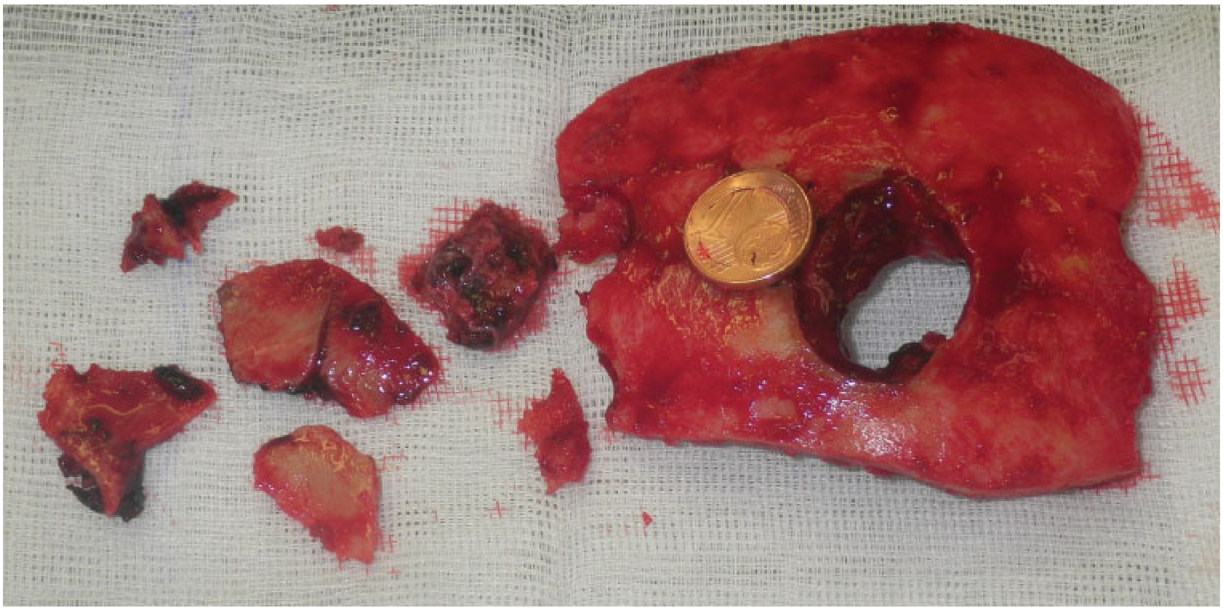

Fig. 4 Left: dislodged intracranial bone fragments. Right: craniotomy flap with bony defect at the bullet entry. The one-cent coin was retrieved from parietal white matter.

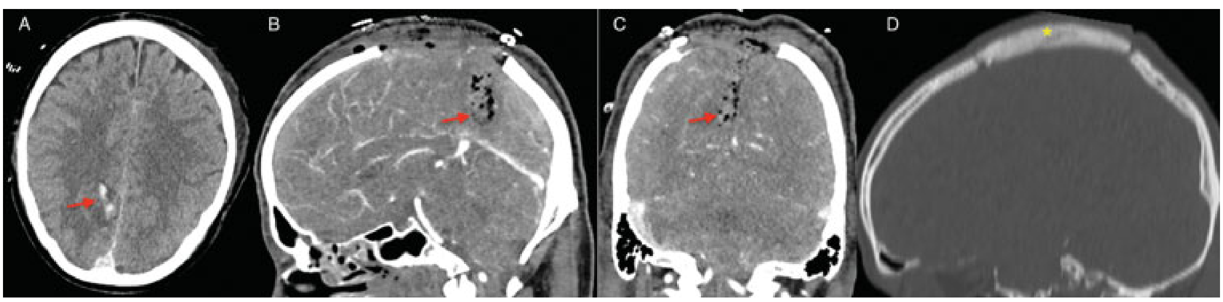

Fig. 5 Postoperative axial CCT (**A**) and sagittal (**B**) and coronal (**C**) CTA confirm complete removal of all bone fragments and the foreign body. Small blood clot and minor intraparenchymal air are detectable (*red arrow*). (**D**) PMMA cranioplasty is shown (*yellow asterisk*). CCT, cranial computed tomography; CTA, computed tomography angiography; PMMA, polymethyl methacrylate.

Postoperative Clinical Course

CT scan of the brain performed 12 hours after surgery confirmed complete removal of all bone fragments and the foreign body. A small (1 cm^2) blood clot was detected in the resection cavity (►**Fig. 5**). The SSS was obliterated from the impact point to the confluens during repeat CTA (►**Fig. 6**). However, no venous infarction was evident either clinically or radiologically.

The patient was successfully weaned from the respirator and extubated on the 3rd postoperative day. A mild organic psychosis was the only neurological finding. On postoperative day 10, the bony defect was reconstructed with a PMMA (polymethyl methacrylate) cranioplasty (►**Fig. 5**). The patient was then sent to neurologic rehabilitation. During follow-up, he was alert and fully oriented, without any focal neurological deficit, but with continuing signs of mild psychosis. The money coin was used by the patient during the suicide attempt to increase the effect of the bolt shot—this was the result of further investigation.

Discussion

Penetrating brain injury is quite rare in Germany. It represents a heterogeneous group of open injuries with direct sharp impact causing laceration of brain parenchyma and neurovascular structures. The mode and extent of the lesion is influenced predominantly by the properties of the foreign body. They include its kinetic energy, size and shape, angle of impact, and penetrating power against various tissues (namely skin, bone, dura, and brain).[3] Kinetic energy is mainly determined by the velocity and less by the mass of the foreign object ($E = 1/2\, mv^2$).[4] The extent of the lesion is influenced by ballistic properties of the projectile and grossly by the secondary lesions, e.g., bony fragments penetrating the skull and brain, and can be predicted within certain limits.[5] Our case of a captive bolt gun lesion demonstrates various difficulties met with a standardized treatment algorithm. Although skull fractures traversing cerebral sinuses are seen frequently, complete traumatic lacerations and occlusions of the mid and posterior third of the SSS are quite rare.[6] A sound anatomic and pathophysiologic understanding is necessary, when treating

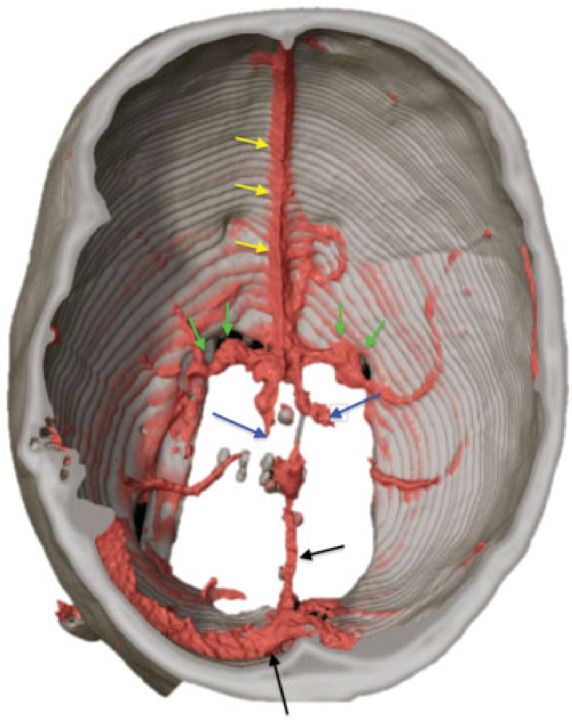

Fig. 6 Three-dimensional reconstruction of venous phase CT angiography (performed 12 hours post OP). The rostral segment of the superior sagittal sinus is intact (*yellow arrows*). Flow void of the severed sinus segment (*blue arrows*). Dilated bridging veins as part of the collateral circulation (*green arrows*). Additional collateral veins feeding the transverse and rectus sinus (*black arrows*). CT, computed tomography; OP, operation.

these lesions. The SSS drains the upper part of the frontal, parietal, and occipital lobes and the rostral part of the orbital part of the frontal lobe. Blood can be drained via collateral venous pathways in the event of SSS obstruction. Such collateral circulation is mainly present in the rostral part of the SSS and significantly less in the middle and posterior third of the SSS. For this reason, obstruction of the rostral third of the SSS is much better compensated, depending on residual perfusion and individual collateral circulatory capacity. On the contrary, obstruction of the middle and posterior third will oftentimes result in neurologic decline due to venous stasis, intracranial hypertension, and even hemorrhagic infarction.[7] It should be noted that signs of SSS thrombosis can develop over some time and may not be present immediately, neither clinically nor radiologically.[8]

CCT imaging is the gold standard for setting the diagnosis.[9] The extent of parenchymal contusion, intracerebral hemorrhage, and midline shift can all be determined instantly. Bone windowing enables precise delineation and localization of impression fractures. Sagittal and coronal as well as three-dimensional-CT reconstructions may add valuable information in complex lesions. If a vascular trauma is suspected, a CTA is obligatory. Unexplained subarachnoid hemorrhage or delayed (epi-, subdural, or intracerebral) hematoma evolution may hint to occult vascular damage.[10] Digital subtraction angiography is superior to CTA in cases of complex vascular trauma.[11] We strongly advise against initial magnetic resonance imaging (MRI) imaging in cases of penetrating head injury, since subtle, albeit dangerous motion of intracranial ferromagnetic debris may occur due to the magnetic field.[4] However, MRI is helpful in the postoperative course evaluating axonal shear injury, smaller contusions, and vascular patency.[9,12]

In contrast to blunt head injury, the role of regular intracranial pressure (ICP) measurement is unequivocal in penetrating head injury, with little reliable evidence.[13] Recommendations exist depending on the initial clinical status, presence of edema, and planned surgical intervention (e.g., temporary vascular clipping, etc.).

Lacerations of the SSS especially in its middle and posterior parts have a high rate of morbidity and mortality.[6] They should be managed individually and oftentimes require a multidisciplinary approach. Impression fractures overlying or crossing the sinus with no or minor dislocation may be treated conservatively, if the vascular lumen is not narrowed and the patient is asymptomatic.[7] Any significant vascular compromise or presence of open head injury necessitates a surgical procedure.[14] Elevation of impression fractures over the SSS is not recommended by the authors, since it may cause brisk venous bleeding which may be difficult to control.[8] A craniotomy encompassing the impression gives proximal and distal control of the sinus via temporary ligation or clipping. ICP should be monitored during temporary sinus occlusion, since it may cause abrupt and significant elevations.[15] Small sinus wall lacerations can be managed by direct suture and placing a collagen membrane (e.g., TachoSil) or muscle patch.[16] A ligature of the SSS is well tolerated in the anterior third for uncontrollable hemorrhage, but problematic in the middle and posterior third.[6,8] Reconstructions of the sinus wall with the use of venous grafting and/or shunting have been described, but are technically demanding and time-consuming, and therefore of less value in emergency situations.[17,18] In our case, the sinus lumen was fully thrombosed proximal and distal to the lesion, and no signs of intracranial hypertension were noted. The affected sinus was therefore ligated proximally and distally without sequelae, and reconstruction was not needed.

Extreme head flexion or rotation can decrease venous outflow and thus should be avoided when positioning the patient.[8,17] Opening of the SSS can lead to air embolism and severe cardiac insufficiency, since the sinus walls are not collapsible. We recommend continuous monitoring of air embolism with precordial or transesophageal Doppler sonography. While positioning of the head on or below the cardiac level may decrease the probability of air embolism, it can increase blood loss from the SSS. If the sinus lumen is found open during surgery, immediate irrigation of the operative field may reduce the risk of air embolism. Hemorrhage from the SSS can lead to hypotension and—together with posttraumatic coagulopathy—may exacerbate a life-threatening vicious circle. Early diagnosis with rotational thromboelastometry as well as timely and adequate transfusion of red blood cell and fresh-frozen plasma may mitigate this complication.[19]

Prophylactic antibiotic treatment has been demonstrated to lower morbidity and mortality in penetrating head trauma, and should be initiated early.[5,20] The authors recommend a combination of penicillin plus second-generation cephalosporin plus metronidazole given intravenously over 7 to 10 days.[8] Postoperative cerebrospinal fistulas will increase the risk of infection, especially meningitis.[14] Any dural perforation encountered intraoperatively should be closed in a watertight fashion using direct suturing. If a direct repair is not achievable, a collagen biomatrix (e.g., TissuDura) can be placed and sutured.

Ictal events seen early following penetrating head trauma can lead to posttraumatic epilepsy and should initiate use of antiepileptic drugs (e.g., phenytoin) for 7 days.[21,22]

Summary

Severe traumatic lesions of the SSS are rare. They are often only found by CT during initial diagnostic evaluation. Although these lesions are prone to complications, prompting surgical intervention, a thorough radiological examination and multidisciplinary treatment planning are warranted. In this way, otherwise uncontrollable peri- and intraoperative complications with high rates of morbidity and mortality may be avoided, leading to better outcomes.

Conflict of Interest
None declared.

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