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Nail Penetration in the Superior Sagittal Sinus: A Case Report of a Nail Gun Injury

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Abstract

The number of penetrating brain injuries (PBI) is low, and the materials of PBI, including bullets, nails, chopsticks, wood, and missiles, vary widely. We report a case in which a nail penetrated the superior sagittal sinus (SSS) and advanced between the cerebral falx but was managed favorably. A 25-year-old male was bruised by a nail gun falling on his head, triggering the ejection of a 3-inch nail into his head. He presented with no symptoms other than mild bleeding and head pain. The patient did not notice the nail injection. Computed tomography (CT) and angiogram revealed that the nail entered parallel to the midline in the interhemispheric fissure through SSS, and there was no intracranial hemorrhage. A bilateral frontoparietal craniotomy was performed with the nail left fixed to the skull. After confirming that the cerebral falx enveloped the entire length of the nail, we extirpated it and sealed the entrance to the SSS. The patient recovered with no neurological deficits, and postoperative images confirmed preservation of the antegrade venous return of the SSS. We observed a case of nail penetration in the SSS. It was essential to perform a thorough imaging examination and the extraction under direct observation using a microscope.

Keywords: traumatic brain injury, penetrating head injury, nail gun

Introduction

Penetrating brain injury (PBI) is one of the rarest head injuries. The materials involved in PBI, including bullets, nails, chopsticks, wood, and missiles, vary widely. The type of foreign body, location and depth of the injury, and surrounding vascular structures require different treatment strategies and ingenuity of the neurosurgeon. A nail gun is used at construction sites to eject nails at high speeds continuously. It can injure others and has been used to commit suicide. Nail guns sold in Japan have a safety mechanism called trigger safety, which prevents the nails from being fired unless the user presses the tip of the nail gun against the target.

Although various traumatic brain injuries (TBI) caused by nail guns have been reported, there are few reports of foreign bodies penetrating the superior sagittal sinus (SSS). Based on a literature review, we report our experience with a case of nail penetration in the SSS, where a preoperative assessment strategy and intraoperative manipulation led to prompt treatment and a good outcome.

Case Report

A 25-year-old male was admitted to our hospital with a PBI. While working as a carpenter without a helmet, a nail gun accidentally fell on his head. His level of consciousness was 15 points on the Glasgow Coma Scale (GCS) (E4 V5M6), with no apparent neurological deficits. He felt an impact on his head; however, he did not notice the nail penetration. The bleeding from the skin wound had stopped on arrival (Fig. 1-A).

Computed tomography (CT) of the brain showed that the nail had penetrated the midline of the head from anterior to posterior (Fig. 1-B). CT angiography and CT venography (CTA/CTV) revealed that the nail did not reach the

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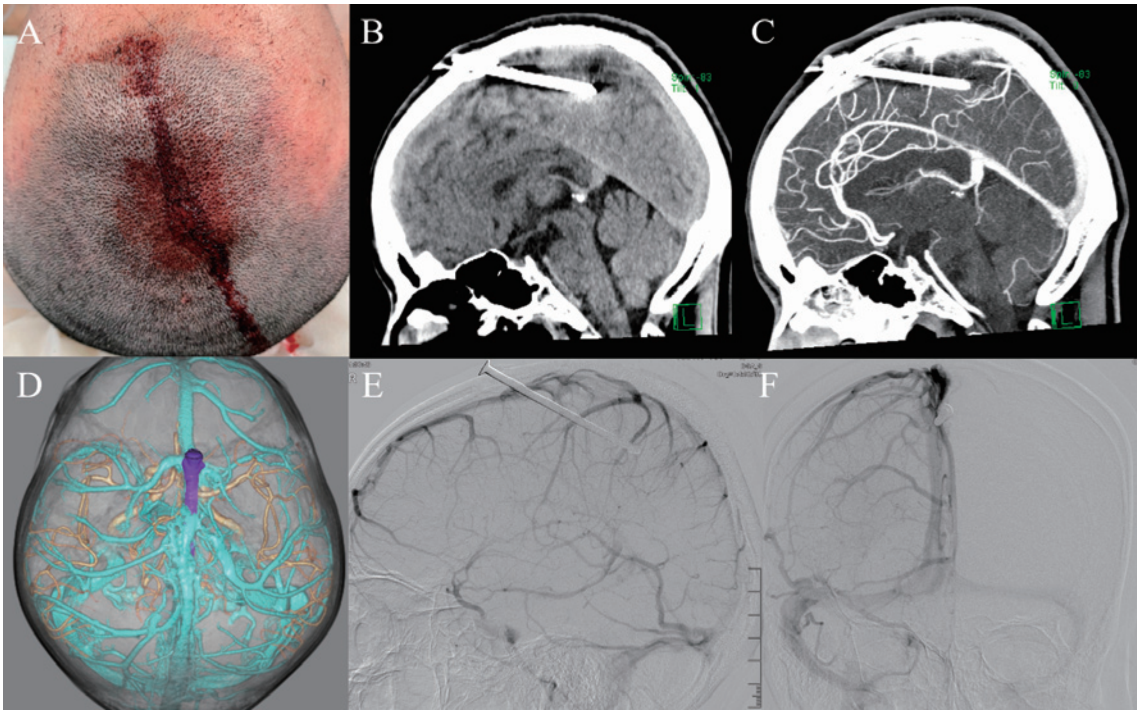

Fig. 1 Presentation of the case.
(A) The scalp does not show the presence of a nail head. (B) CT shows a nail in the intracranial cavity, from anterior to posterior. (C-D) CTA/CTV image showing the nail stuck in the midline. (E-F) Right common carotid angiography shows a nail penetrating the SSS without occlusion of the SSS.
CT: Computed tomography. CTA/CTV: Computed angiography and venography. SSS: superior sagittal sinus

anterior cerebral artery (ACA) but penetrated the SSS (Figs. 1-C and 1-D). It was unclear whether the nail tip was on the left or right side, possibly due to nail artifacts. Cerebral angiography revealed that the SSS was perfused in antegrade flow without occlusion or extravasation. The nail tip did not reach the inferior sagittal sinus and penetrated the SSS; the width of the SSS was 6 mm (Figs. 1-E and 1-F).

After initial antibiotic therapy (2 g ceftriaxone) in the emergency department, surgery was performed 6 h after the injury (2 h after arrival) under general anesthesia. The head was fixed at the midline in the supine position. The procedure was as follows: a bicoronal "M" shaped skin incision was made, including the entry point of the nail (Fig. 2-A). After making two burr holes over the nail head in the median plane and two burr holes over the SSS 4 cm posteriorly, craniotomy was performed with the nail leaving the surrounding bone (Figs. 2-B and 2-C). A U-shaped dural incision that remained at the midline was made. The cerebral falx from the interhemispheric fissure was observed under a microscope. The nail did not protrude from the cerebral falx into the subdural space on either side (Figs. 2-D and 2-E), indicating that the nail penetrated only the intrafalx. The bone around the nail insertion site was separated, and the nail was carefully removed from the bone. Active venous bleeding occurred at the excision site. GoreTex cut into 6 mm diameter circles was placed to cover the hole, and a gelatin sponge with fibrin glue was placed on top of the GoreTex (Figs. 2-F and 2-G). The nail was 7.5 cm long and 3.0 mm in diameter (Fig. 2-H). A postoperative CT showed bleeding from the operative field at the cerebral falx and cerebellar tent (Figs. 3-A and 3-B). CTA/CTV confirmed the SSS flow (Fig. 3-C).

Postoperatively, for bacterial meningitis, meropenem 6 g/day and vancomycin 2 g (the initial dose was adjusted according to therapeutic drug monitoring) for 2 weeks, and the inflammatory response on blood sampling improved rapidly. Two weeks postoperatively, magnetic resonance imaging (MRI) revealed no findings consistent with an intracranial abscess and no parenchymal brain damage from the nail (Figs. 3-D, 3-E and 3-F). MRI performed five months after surgery showed no evidence of intracranial infection. The patient showed no neurological abnormalities and returned to work under the same conditions as before the accident.

Discussion

PBIs account for <0.4% of all TBI.[1,2] Minimizing damage to the brain parenchyma and surrounding vascular structures is crucial in their management. Despite the poor prognosis of PBI, the prognosis of nail injuries is relatively

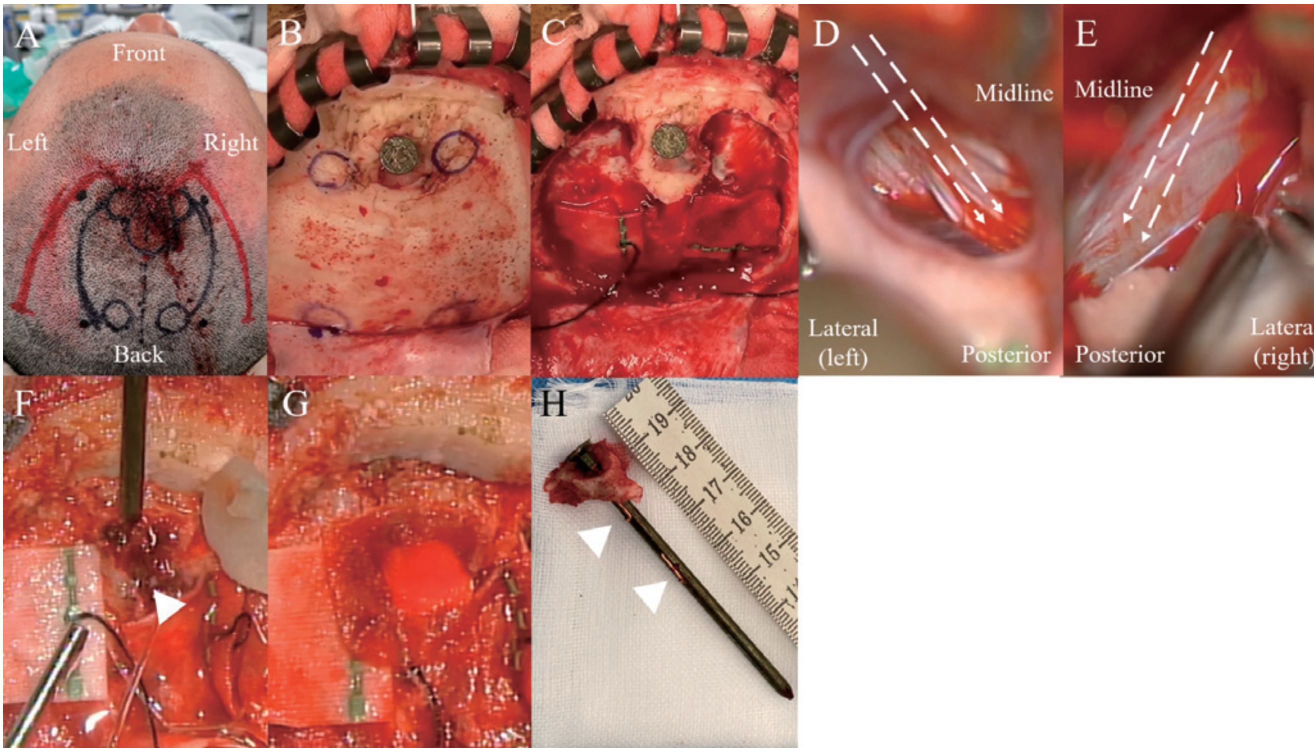

Fig. 2 Surgical intervention and management after nail extraction.
(A) A bicoronal "M" shaped skin incision, including the entry point of the nail. (B) Intraoperative findings: Four burr holes were planned after the skin incision. (C) After the craniotomy, the bone around the nail was left in place. (D, E) Intraoperative images of the skull from the left and right sides. Dotted arrows indicate nail direction. (F) Immediately after the nail was removed. The arrowhead (white) indicated a hole in the SSS. (G) GoreTex cut into 6 mm diameter rounds was placed to cover the hole. A gelatin sponge with fibrin glue was placed on top of GoreTex. (H) Extracted nails. Arrowheads indicate the wires remaining on the nails.

good if there are no large vessel or brainstem injuries.[3,4)]The postoperative complications of PBI include meningitis, brain abscess, and encephalitis. Vascular complications after PBI range from <5% to 40%,[5,6)] with traumatic aneurysms as the most common injury.[6)] Traumatic aneurysms, which tend to occur within 3 weeks of injury, are known to be particularly dangerous, with a reported mortality rate of 50% if ruptured.[7)] Pseudoaneurysms and arteriovenous fistulas occur in 12%-20% of intracranial foreign body cases.[8)] In this case, no infections or traumatic aneurysms appeared at the 3-month follow-up.

PBIs are divided into high- and low-velocity injuries.[9)] A high-velocity injury is defined as an initial velocity of ≥2,000 ft/s (610 cm/s), meaning the injury enters the target at a high speed and temperature. The risk of infection is low; however, brain tissue damage is severe, and the outcome is poor. In contrast, low-velocity injury involves an initial velocity of <2,000 ft/s and penetration at low-velocity and low temperature. The risk of infection is high; however, damage to the surrounding brain tissue is low. The nail gun ejected nails at an initial velocity of 112-144 ft/s (340-440 cm/s), causing low-velocity injuries. The SSS injury was minimal in this case due to the low-velocity injury. In addition, because the nail entered directly in the midline, there was no damage to the brain parenchyma and arteries (distal ACA and others).

The severity of PBI caused by intracranial foreign bodies highly depends on the anatomical structures penetrated. In particular, the SSS is a critical structure. Its injury may compromise venous perfusion, while occlusion may lead to death.[2,10)] There have been only reports of nail penetration into the SSS.[3,11,12)] The mortality due to venous sinus injury in non-PBI was 41.7% for transverse sinus, 25% for cavernous sinus, 25% for sigmoid sinus, and 16.7% for SSS. SSS mortality is low among sinus injuries.[13)] The injury site with the highest mortality is the posterior portion of the SSS.[14)] CTA/CTV is useful in determining the relationship of the nail to the SSS and other vascular structures, such as the ACA, when a nail had punctured the midline of the head;[2)] however, it may not be able to determine the exact location due to metal artifacts. Assessing the dynamic flow in the venous sinuses (anterograde or retrograde) is also impossible. Therefore, except in emergencies, cerebral angiography is appropriate.

There are several points to consider when removing the nail penetrating the SSS: 1) craniotomy is performed, leaving the bone around the nail to maintain nail stability; 2) to prevent intraoperative air embolism, the head should

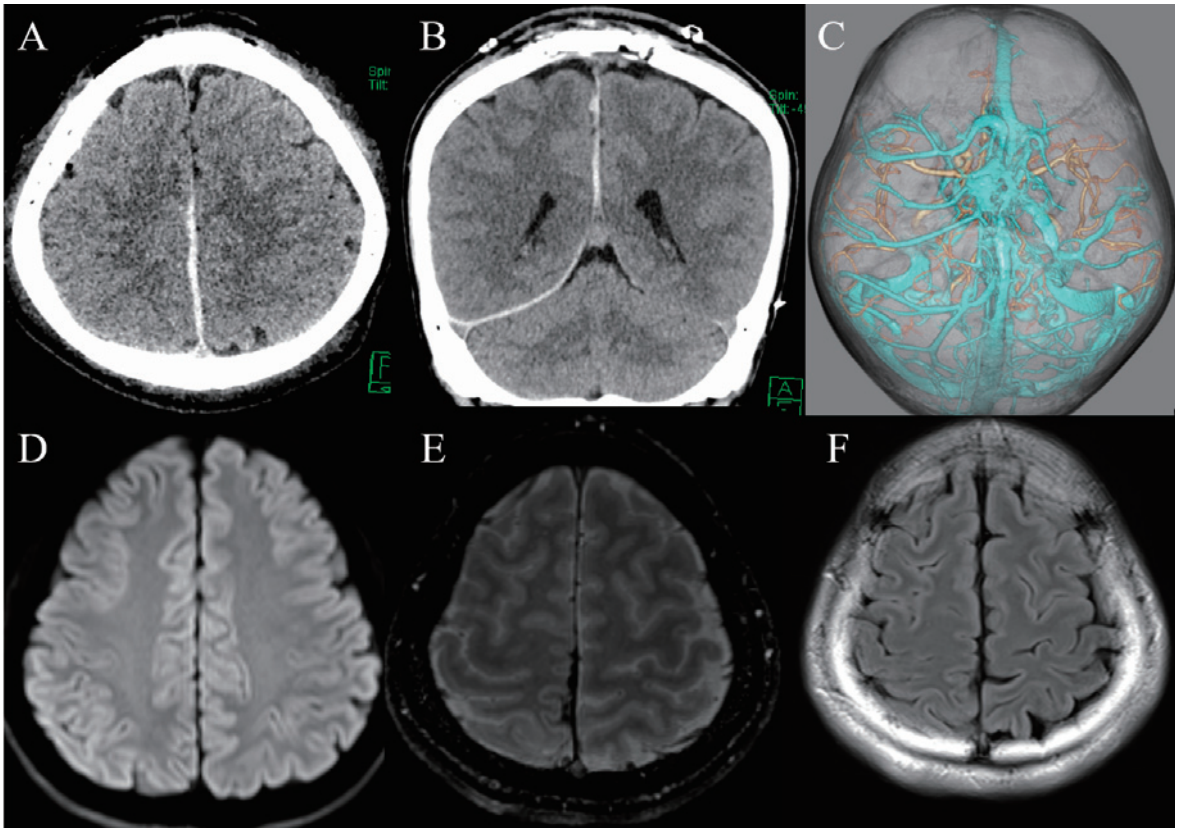

Fig. 3 Postoperative imaging and follow-up.
(A, B) Postoperative CT showed bleeding from the operative field along the cerebral falx and a small amount of bleeding in the cerebellar tent. (C) A contrast-enhanced CTV showed that the SSS was not obstructed. MRI at two weeks shows no abscess formation (D: diffusion-weighted images) and no parenchymal injury (E: T2-weighted images, F: fluid-attenuated inversion recovery).

not be elevated too high, and water should be continuously applied to the hole of the SSS, and 3) the dural incision site should be adjusted according to the position of the bridging vein under direct observation of the interhemispheric fissure. In addition, we consider it particularly important that 4) the nail should be removed under direct observation to stop the bleeding and repair the injured SSS area quickly. There are previous reports of sinus repair using the temporal muscle and fascia,[3] suture closure using 4-0 nylon,[11] hitching up the dura to the bone adjacent to the sinus, duraplasty, and ligature closure of the anterior and posterior sinuses of the injured area[12] for hemostasis. In this case, hemostasis was achieved by cutting a piece of GoreTex to cover the hole in the SSS and using a gelatin sponge with fibrin glue to cover the GoreTex. Covering the hole in the SSS with GoreTex could reduce the risk of SSS obstruction due to sinus sutures and prevent air embolism into the SSS. Although these hemostatic methods are available, removing the nail under direct microscopic observation is more important to manage vascular and parenchymal injury. Even if the preoperative images show no significant damage and the nail can be removed intact, there is a possibility of damage that imaging does not detect. If a clot on the penetrated nail obstructed the SSS, removing the nail would or would not recanalize the SSS. In that case, we observe the clot washing out of the SSS for some time after nail removal. Further maneuvers may be required, such as temporally clipping of the distal side of the SSS, evacuating the clot, and suturing the torn SSS. If the nail has penetrated the bridging vein, reconstruction by compression with gelatin sponge or by suturing of the vein would be attempted. However, it would be difficult to preserve the venous return and to avoid cerebral congestion and bleeding. As mentioned above, this is a low-velocity injury, and considering the risk of infection, it is safer to use temporal muscle or fascia than GoreTex. In this case, we used GoreTex, which has a higher sealing performance than temporal muscle or fascia and has a lower risk of inducing blood clots in the venous sinus than gelatin sponge, because we confirmed under direct observation that the nail only penetrated the intrafalx. There was no connection with the subdural space.

Traumatic venous sinus thrombosis (VST) secondary to TBI occurred in 1.3% of patients, 37% of whom had venous sinus occlusion. Of the patients with VST, 9% were treated with anticoagulation.[15] In this case, there was no obstruction or stenosis in the SSS at postoperative CTV, and anticoagulation was deemed unnecessary. The infection risk due to PBI must always be considered. Complications such as meningitis or encephalitis can lead to prolonged hospitalization and neurological sequelae, so appropriate antibiotic therapy is recommended.[3)]

The dura mater consists of two layers: the outer layer is the periosteal dura, and the inner layer is the meningeal dura. The periosteal dura is attached to the periosteum of the neurocranium, and the meningeal dura covers the brain and spinal cord. The SSS is surrounded by the periosteal dura and the meningeal dura, and the cerebral falx is the structure that extends vertically from the SSS. The cerebral falx is formed by the median junction of two meningeal dura. In this case, the nail remained in the cerebral falx due to the structure of the two meningeal dura, which can be detached in the middle of the dura.

Conclusion

In nail injuries, it is important to fully confirm the location of the major vascular structures and nails using CTA/CTV and cerebral angiography before surgery. It is safer to remove the nail under direct observation using a microscope. This technique allows you to deal with any unexpected damage safely.

Human and Animal Rights

The authors declare that the work described herein does not involve experimentation with humans or animals.

Informed Consent and Patient Details

The authors declare that they obtained written informed consent from the patient and that this report contains no personal information that could lead to their identification.

Conflicts of Interest Disclosure

The authors declare no conflict of interest.

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