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Delayed-Onset Seizures Following Self-Inflicted Nail Gun Injury to the Head: A Case Report and Literature Review

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Abstract

Nail gun use and its associated incidence of injury have continued to increase since it was first introduced in 1959. While most of these injuries involve the extremities, a subset of patients suffer intracranial trauma. The most recent comprehensive review on this particular subject referenced 41 cases and advocated for further discussion regarding proper treatment plans for these individuals. We present the case of a 25-year-old who suffered 35 self-inflicted penetrating head wounds from a nail gun after suffering an amputation injury at his job site. No neurological deficits were present on his arrival to the emergency room. He underwent surgery to treat his arm wound and remove 13 of the 35 nails. The patient was discharged from the hospital on levetiracetam and made a full recovery. Nearly 1 year later, he experienced a seizure at his workplace. However, after resuming his antiepileptic medication, he reports no further complications. This case is distinct for not only being the most nails in a patient's head at presentation, but also following surgery. Utilizing this case, prior review, and 27 subsequent cases, we propose an updated algorithm for diagnosis and treatment of nail-gun-related penetrating head trauma.

Keywords
- nail gun
- penetrating head trauma
- intracranial injury

Introduction

Since it was first introduced in 1959, nail guns have been used in the construction industry to increase productivity. While these devices may ease the workday of their operators, their use is associated with risk of injury, accounting for an estimated 37,000 emergency room visits each year.[1] The vast majority of these injuries involve the extremities; however, there is a subset of patients who suffer intracranial trauma. Surprisingly, this type of nail gun injury is often associated with favorable clinical outcomes. However, there are multiple reports that suggest such an injury can lead to permanent neurologic impairment or death.[2–4] A 2012 review of 41 nail gun head trauma cases suggested that further investigation is needed to develop a proper treatment algorithm for

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these individuals, with more focus on appropriate antibiotic and seizure prophylaxis.[5]

The following case details the clinical course of a patient who suffered 35 self-inflicted penetrating head wounds from a nail gun after accidently amputating his hand. An unfortunate outcome of this patient's nail gun trauma was late-onset posttraumatic seizures (PTSs). With this case, we present a comprehensive review of nail gun injury reports. Based on our findings, we propose the most up-to-date algorithm for diagnosis and treatment of intracranial nail gun injuries.

Materials and Methods

A literature search on PubMed using the phrases "nail gun," "penetrating head trauma," and "intracranial injury" yielded 57 articles from both national and international journals. Non-English language was not a disqualifying factor in this review. The current case was included in the analysis. In total, the cases of 68 patients were reviewed with attention to patient condition at presentation, diagnostic techniques, treatment strategies, and outcomes.

Case Report

A healthy 25-year-old male construction worker was transported to the trauma center following an injury at his job site. The patient reported accidentally placing his left hand in front of a circular saw resulting in a complete amputation of the appendage. He then fired approximately 35 nails into his head using a pneumatic nail gun in an attempt to "dull the pain." He was subsequently transported to the hospital and on arrival, his chief complaint included left arm pain and a headache. He denied any loss of consciousness. Initial examination was significant for a complete traumatic amputation at the level of his left wrist, with bleeding controlled by a tourniquet. There were numerous finishing nails protruding from his head and multiple puncture wounds scattered on his scalp. He was awake, alert, and oriented, with a Glasgow Coma Score (GCS) of 15. Radiological evaluation included an X-ray of the left upper extremity that revealed a transected hand at the level of the proximal metacarpal line. X-ray and a nonenhanced computed tomography (CT) scan of his head revealed an abundance of finishing nails perforating the calvarium (►**Fig. 1**), with the CT scan showing the nails entering the brain parenchyma with subarachnoid blood bilaterally. At least one nail entered the interhemispheric fissure. Furthermore, there were multiple nails that remained extracranial and several that entered the cerebral cortex.

The patient was promptly evaluated by both a plastic surgeon and a neurosurgeon. He was then taken to the operating room for scalp debridement and hand reimplantation. Thirteen of the nails that exclusively penetrated soft tissue were removed, the scalp was debrided, and hemostasis was obtained. Due to the large number of nails deep within the brain parenchyma and the associated risk of removal, as well as the patient's intact neurologic exam, no attempt was made to remove the remaining 22 nails embedded in the calvarium. A cerebral arteriogram revealed no major intracranial arterial or venous injury.

Fig. 1 Head X-ray at presentation. Coronal head X-ray of the patient demonstrating a total of 35 nails that were within the calvarium.

On postoperative day 1, the decision was made to reamputate the patient's hand due to ischemic changes. The patient tolerated this procedure well and the remainder of the patient's hospital course was uneventful. He completed a 7-day course of amoxicillin-clavulanate, received tetanus prophylaxis, and was maintained on a therapeutic level of phenytoin. He was discharged home and was continued on his anticonvulsant regimen.

Approximately 15 months later, the patient returned to the trauma center following a witnessed seizure. He was confused and combative on arrival and seized in the trauma bay. The patient denied previous seizures but admitted to recently stopping his anticonvulsant. A CT scan showed no new lesions and an electroencephalogram revealed bi-hemispheric cortical abnormalities without any focal epileptiform activity. The hospital course was otherwise unremarkable, and the patient was discharged home on levetiracetam. He has since returned to work and is living independently with no other apparent long-term complications.

Results

A total of 68 patients were included in the literature review (►**Table 1**). The patient population consisted of 67 men and 1 woman, 97% of whom were adults. Presentations of these individuals varied: 32 (47%) were neurologically intact, 29 (42%) suffered focal deficits, and 7 (10%) were comatose. Headache was the most commonly reported symptom in patients who were neurologically intact. At the time of

Table 1 Summary of reviewed cases of penetrating cranial nail gun trauma

Author	Year	Sex	Presentation	Angiography	Intervention	Discharge	Complications	Antibiotics	Seizure prophylaxis
Adamo	2010	M	Neck pain	CT angiogram, Catheter	Extra ventricular drain, ventricular peritoneal shunt, removal without craniotomy	Intact	Cerebellar edema, HCP, left VA dissection, VPS	No comment	No comment
Al-Mefty	1986	M	Right hemiparesis	Catheter	Craniotomy, surgical removal	Right hemiparesis	Left transverse sinus injury	Broad-spectrum antibiotics (unspecified)	No comment
		M	Limited right EOM	Catheter	Craniotomy, surgical removal	Intact	None	Broad-spectrum antibiotics (unspecified)	No comment
Alain	2018	M	Intact	CT angiogram	Craniectomy, surgical removal	Intact	None	Vancomycin, ceftriaxone	Seizure prophylaxis (unspecified)
Awori	2017	M	Vision loss, headache	CT angiogram	Surgical removal (unspecified)	Visual changes	Pain and numbness in VI distribution	Aztreonam, metronidazole, vancomycin	Levetiracetam
Beaver	1999	M	Comatose	None	Withdrawal of care	Deceased	IVH	Deceased	Deceased
Bilotta	2007	M	Headache, intact	Catheter	Craniotomy, surgical removal	Intact	None	Broad-spectrum antibiotics (unspecified)	No comment
Blankenship	1999	M	Word-finding difficulty	Catheter	Double concentric craniotomy, surgical removal	Intact	Middle cerebral artery branch pseudoaneurysm	No comment	No comment
Bock	2002	M	Left hemiparesis	None	Craniotomy, surgical removal	Intact	None	No comment	No comment
Borzone	1986	M	Intact	Catheter	Craniotomy, surgical removal	Intact	None	No comment	No comment
Bragg	2006	M	Intact	Catheter	Craniotomy, surgical removal	Intact	Adjacent to the sinus	Antibiotics	No comment
Buchalter	2002	M	Jaw pain, trismus	Catheter	Craniotomy, surgical removal	Intact	IPH	No comment	No comment
		M	Aphasia, neck stiffness	Catheter	Craniotomy, surgical removal	Memory loss, aphasia	None	No comment	No comment
Carnevale	2016	M	Intact	None	Craniotomy, surgical removal	Intact	None	Vancomycin, cefepime, metronidazole	No comment
Demetriades	2007	M	Headache, intact	None	Surgical removal (unspecified)	Intact	None	No comment	No comment
Dow	2018	M	Right visual loss	CT angiogram	Dural venous sinus embolization, surgical removal	Residual visual loss	None	No comment	No comment
Eachempati	1999	M	Hearing loss of right ear	Catheter	Surgical removal (unspecified)	Intact	None	No comment	No comment
Englot	2009	M	Right arm weakness	Catheter	Double concentric craniotomy, surgical removal	Residual weakness	Basilar artery injury	No comment	No comment
Ferraz	2016	M	Intact	None	Craniotomy, surgical removal	Intact	None	Broad-spectrum antibiotics (unspecified)	Seizure prophylaxis (unspecified)
Hiraishi	2009	M	Hemiparesis and aphasia	Catheter	Endovascular trapping of ICA	Intact	Unstable ICA stenosis, ischemia	No comment	No comment
Hoey	2020	M	Headache, intact	CT angiogram	Local debridement without removal	Intact	Delayed seizures	Amoxicillin-clavulanate	Levetiracetam

Table 1 (*Continued*)

Author	Year	Sex	Presentation	Angiography	Intervention	Discharge	Complications	Antibiotics	Seizure prophylaxis
Hull	2019	M	Dysarthria, left facial droop	None	Surgical removal (unspecified)	Verbal fluency loss, memory impairment	None	Broad-spectrum antibiotics (unspecified)	No comment
Isaacs	2015	M	Seizure, CN VI palsy, left facial droop, left weakness	CT angiogram	Craniotomy, surgical removal	Intact	None	Broad-spectrum antibiotics (unspecified)	No comment
Jacob	2005	F	Right hemiparesis, left NR pupil	Catheter	SOC craniectomy	Residual weakness, NR pupil	Left vermian posteroinferior cerebellar artery branch transected	Unable to access article	Unable to access article
Jeon	2014	M	Right hemiparesis	None	Craniectomy, surgical removal	Right hemiparesis	None	Ceftriaxone, chloramphenicol, metronidazole	No comment
Jithoo	2001	M	Intact	Catheter	Surgical removal (unspecified)	Intact	Pericallosal artery aneurysm	Unable to access article	Unable to access article
Kusanagi	2000	M	Right-jaw pain	Catheter	Surgical removal (unspecified)	Intact	Anterior and posterior pituitary dysfunction	No comment	No comment
Lazic and Strugar	2009	M	Comatose, NR pupils	CT angiogram	Local debridement without removal	Slow mentation, dysarthria, internuclear ophthalmoplegia	None	No comment	No comment
Lee and Oh	2007	M	Decreased V2 sensation	Catheter	Removed in the operating room without craniotomy	Intact	None	No comment	No comment
Litvack	2006	M	Headache, right CN VI palsy, hemifacial weakness	Catheter	Craniotomy, surgical removal, ICP monitor	Dysarthria, hemifacial weakness	None	No comment	No comment
Luo	2012	M	Headache, intact	CT angiogram	Craniectomy, surgical removal	Intact	None	No comment	No comment
		M	Hemiparesis	CT angiogram	Craniotomy, nails left in place	Weakness	None	No comment	Seizure prophylaxis (unspecified)
Makoshi	2016	M	CN VI, VIII, XI, XII injury, left-sided weakness	CT angiogram	Craniotomy, surgical removal	Intact	Moderate cognitive impairment	Broad-spectrum antibiotics (unspecified)	Phenytoin
		M	Intact	CT angiogram	Craniotomy, surgical removal	Intact	Mild-moderate cognitive impairment	Broad-spectrum antibiotics (unspecified)	Phenytoin
		M	Intact	None	Craniotomy, surgical removal	Intact	None	Broad-spectrum antibiotics (unspecified)	Phenytoin
		M	Intact	CT angiogram	Craniotomy, surgical removal	Gait dysfunction	None	Broad-spectrum antibiotics (unspecified)	Phenytoin
Min	2017	M	Comatose	None	Bilateral frontal craniotomy, surgical removal	Intact	None	Third-generation cephalosporin	Seizure prophylaxis (unspecified)
Morita	2017	M	Comatose	CT angiogram, CT venography	Surgical removal, unspecified, extraventricular drain	Intact	None	Ceftriaxone, metronidazole	No comment
Nitsch	2007	M	Toothache, intact	Catheter	Removal without craniotomy	Intact	None	Amoxicillin-clavulanate	No comment
Nussbaum	2019	M	Intact	Catheter	Craniotomy, surgical removal	Intact	None	Broad-spectrum antibiotics (unspecified)	No comment
Oh	2014	M	Comatose	CT angiogram	Craniotomy, surgical removal	Minimal brain stem function	Hydrocephalus	Ceftriaxone	No comment
Okada	1993	M	Headache, intact	Catheter		Intact	None	Cefotiam	No comment

(*Continued*)

Table 1 (*Continued*)

Author	Year	Sex	Presentation	Angiography	Intervention	Discharge	Complications	Antibiotics	Seizure prophylaxis
					Double concentric craniotomy, surgical removal				
Pomara	2012	M	Headache, intact	None	Craniotomy, surgical removal	Deceased	Death	Deceased	Deceased
Panourias	2006	M	Hemiparesis	Catheter	Craniotomy, surgical removal	Intact	Extravasation	No comment	No comment
Rennert	2016	M	Expressive aphasia	Catheter	Selective carotid embolization, surgical removal	Left weakness	Delayed pseudoaneurysm, delayed seizures	Broad-spectrum antibiotics (unspecified)	No comment
Rezai	1994	M	Comatose	Catheter	Extra ventricular drain, surgery refused	Deceased	Left posterior cerebral artery pseudoaneurysm, IVH, SAH	Deceased	Deceased
Salar	2004	M	Confusion	Catheter	Surgical removal (unspecified)	Frontal syndrome	None	No comment	Carbamaze-pine
Sani	2005	M	Word-finding difficulty	CT angiogram	Double concentric craniotomy, sinus repair	Intact	Superior sagittal sinus injury	Broad-spectrum antibiotics (unspecified)	No comment
Scarfo	1990	M	Right monocular blindness	None	Craniotomy, surgical removal	Stable	EEG abnormality (no seizure)	Unable to access article	Unable to access article
Schaller	2008	M	Right frontalis weakness	Catheter	Removal without craniotomy	Intact	Small IPH and EDH	No comment	No comment
Selvanathan	2007	M	Psychosis	Catheter	Removal without craniotomy	Intact	Left petrous ICA pseudoaneurysm	Amoxicillin, gentamicin, metronidazole	No comment
		M	Visual changes	Catheter	Removal without craniotomy	Visual changes	None	No comment	No comment
		M	Headache, intact	None	Removal without craniotomy	Intact	None	Broad-spectrum antibiotics (unspecified)	No comment
Spennato	2004	M	Jacksonian seizure	None	Double concentric craniotomy	Intact	None	No comment	No comment
Springborg	2007	M	Left hemiparesis	None	Burr hole, surgical removal	Left hemiparesis	Possible meningitis	Cefuroxime	None
		M	Headache, nasal hemianopsia	CT angiogram	Craniotomy, surgical removal	Nasal hemianopsia	None	Cefuroxime	None
Spiers	1994	M	Intact	None	Burr hole and removal	Intact	None	Unable to access article	Unable to access article
Testerman	2007	M	Headache, intact	Catheter	Craniotomy, surgical removal	Intact	None	No comment	No comment
Thomas and Siu	1987	M	Headache, increased right upper extremity tone	None	Suboccipital craniectomy, surgical removal	Intact	None	Unable to access article	Unable to access article
Viswanathan	1994	M	Comatose	None	Debridement, ICP monitor	Deceased	Death	No comment	No comment
Yuh	2015	M	Dysarthria, left facial droop	CT angiogram	Craniotomy, surgical removal	Intact	Seizure prior to arrival	Broad-spectrum antibiotics (unspecified)	Phenytoin
Winder	2010	M	Left hemiparesis	Digital subtraction angiography	Craniectomy, surgical removal	Intact	Partial seizure	Amoxicillin-clavulanate, flucloxacillin	Phenytoin
Woodall and Alleyne	2010	M	Right pronator drift	None		Right pronator drift	None	No comment	No comment

Table 1 (*Continued*)

Author	Year	Sex	Presentation	Angiography	Intervention	Discharge	Complications	Antibiotics	Seizure prophylaxis
					Double concentric craniotomy				
Wu	1975	M	Headache, dizziness	None	Craniotomy, surgical removal	Left hyperreflexia and decreased left proprioception	None	Unable to access article	Unable to access article
		M	Headache, progressed to hemiparesis	None	Right hemicraniectomy, surgical removal	Intact	Ongoing seizures, meningitis	Unable to access article	Unable to access article
Wu	2018	M	Hemiparesis	Magnetic resonance angiography	Craniectomy, surgical removal	Weakness	None	Ceftazidime and vancomycin	Sodium valproate
		M	Headache, intact	None	Craniectomy, surgical removal	Intact	None	Ceftazidime and vancomycin	Sodium valproate
		M	Headache, intact	None	Craniectomy, surgical removal	Intact	None	Ceftazidime and vancomycin	Sodium valproate

Abbreviations: CN, cranial nerve; CT, computed tomography; EDH, epidural hematoma; EEG, electroencephalography; EOM, extra ocular movement; HCP, hydrocephalus; ICA, internal carotid artery; ICP, intracranial pressure; IPH, intraparenchymal hemorrhage; IVH, intraventricular hemorrhage; NR, non-reactive; SAH, subarachnoid hemorrhage; SOC, suboccipital craniectomy; VA, vertebral artery; VPS, ventriculoperitoneal shunt.
Note: List of articles included in the literature review on penetrating cranial trauma due to nail guns. 68 patients were included in the review.

discharge, 47 (69%) of the patients were neurologically intact, 17 (25%) had focal neurologic deficits, and 4 (6%) died. All patients underwent some form of imaging. Formal catheter angiography was used in 27 patients (40%) and computed tomography angiography (CTA) in 17 (25%).

With regards to treatment, craniotomy or craniectomy was performed in 43 (63%) of the cases, 6 of which were bilateral. Two patients were treated definitively with burr holes. Nail removal without a craniotomy or through an unspecified surgical procedure was reported in 15 (22%) of the cases. Vascular embolization was utilized in two patients. Local debridement without nail removal was performed in three cases. Nails were left permanently in the calvarium in five of the patients.

Commentary on antibiotic use was provided in 33 of the cases, 16 of which did not specify which antibiotics were used. Antiepileptic medications were mentioned in 16 of the reports.

Discussion

Presentation and Outcomes

Patients with intracranial nail gun injuries present with varying degrees of neurologic deficits. Similar to the 2012 comprehensive review, 46% of patients presented with an intact neurological exam. These individuals' most common complaint on admission was headache. Conversely, neurological deficits included: visual loss, hemiparesis, dysarthria, and cranial nerve injuries. Seven patients presented in a comatose state. Many of the patients who presented with deficits improved prior to discharge as 72% of the cases left the hospital with a normal neurological exam.

Imaging

The standard of care for penetrating brain trauma is a non-enhanced CT scan of the head.[6] These images aid in localizing any entry and exit wounds, foreign bodies, hemorrhage, and mass effect. Each of the most recent 28 patients incorporated into the literature review received this imaging as a baseline study for their injury. In addition, current recommendations suggest obtaining a CTA or digital subtraction angiography for any patients with a high likelihood of vascular injury.[7] This additional imaging can help identify vessel penetration, arterial dissection, pseudoaneurysms, and vessel stenosis. In accordance with these guidelines, CTA was the most common form of angiography used in the most recent patients, whereas catheter angiography was used more frequently in the Woodall et al review.

Surgical Approach

Neurosurgical approach to penetrating transcranial injury should vary on a case-by-case basis. While surgery is a major component of the current standard of care, there is no standard for surgical approach.[8] Considerations of the current neurologic status of the patient and potential benefits of the surgery must be weighed against the potential risks of neurosurgical intervention. The objectives of surgery are to remove foreign bodies to decrease risk of infection as well as

addressing any secondary causes of cerebral injury that develop after the initial trauma.[9] These include but are not limited to intracranial hemorrhage due to vascular injury, potential venous infarction secondary to dural venous sinus injury, and development of significant brain edema or hydrocephalus that might require decompression.

When approaching patients with traumatic penetrating brain injury, questions about the location of injury within the brain along with the involvement of vessels, sinuses, and ventricles must all be addressed when planning for surgery. Perhaps most importantly, violation of the protective blood–brain barrier poses a major risk for infection. Any open communication between the central nervous system (CNS) spaces and the outside world that is caused by penetrating injury must be addressed to minimize the risk of infection and immune response. This may require prompt removal of a foreign body or a simple closure of the projectile's track with proper irrigation and wound debridement.

Surgical approach is also dependent on the area of the cortex injured. While neuroplasticity may lead to recovery to some degree, damage incurred during initial injury will be irreversible. Causing further injury to important cortical regions with removal and instrumentation should be avoided. For nail gun injury, risk factors include barbed or ribbed nails along with nails that have glue placed along the length of the nail for better retention.[2] Fracturing of the projectile and/or the skull upon entry increases the risk of foreign body retention, cerebral irritation, and injury with removal. These secondary projectiles pose a risk for vascular injury, which can develop during both an immediate and delayed time course.[10,11] Immediate vascular injury can be visualized and partially addressed with angiogram.[12] Such injury to arteries or major venous systems like dural sinuses and deep draining veins should be addressed intraoperatively as they can lead to massive hemorrhage and infarction. It is important to monitor these patients for later development of pseudoaneurysms, arteriovenous fistulas, and sinus thrombosis if vascular injury is noted at initial presentation.

The surgical approach most often reported in the literature is a craniotomy with removal of the nails. Size and location of the cranial window are all case-dependent. Discussion and collaboration with other surgical specialists is essential for operative planning. Involvement of ophthalmology or otolaryngology may be required if there is injury to the eyes or other region of the anterior skull base.[13] Endoscopic removal of foreign bodies located in the anterior cranial fossa is also a possibility should the injury mechanism and surgeon preference allow.[14] Use of other procedures such as decompressive craniectomy or vessel embolization should be considered on a case-by-case basis.

With the considerations above, removal of all or any foreign bodies is not a requirement. The present case is an illustration of the potential surgical approach to the patient with penetrating brain injury. With 35 nails in his head at presentation, this patient has the most documented nails reported in the literature. During surgery, only 13 nails were removed based on considerations of utility and safety of removal. He was left with 22 nails still in place, making this also the most documented nails remaining in a patient's head postoperatively. His postoperative course with no neurologic deficits, only complicated by development of delayed seizures that are well-controlled on antiepileptics, validates the decision to leave nails in place to avoid further potential brain or vascular injury secondary to surgical removal.

Antibiotic Prophylaxis

Literature has long suggested starting broad-spectrum antibiotics as soon as possible to prevent intracranial infection in penetrating brain injuries.[15] In this analysis, antibiotics were administered in nearly 90% of cases subsequent to the Woodall et al review. Commentary regarding the type of medication varied from "broad spectrum antibiotics" to vancomycin and second- or third-generation cephalosporins.

On the contrary, a 2020 systematic review of civilians with penetrating brain injury states that there are no robust data suggesting the use, type, or duration of antibiotics for such injuries.[16] Rather, current suggestions are based on dated military studies that may be inappropriately extrapolated to include nail gun injuries.[16] Similarly, a multicenter trial completed by the Eastern Association of Surgery and Trauma reviewed patients from 17 different centers over the past 11 years who suffered penetrating traumatic brain injuries (TBIs).[17] The group found no reduction in intracranial infection with the use of antibiotics. Instead, they found invasive intracranial pressure monitoring and surgical intervention to be risk factors for infection. Interestingly, the paper suggests that it may be appropriate to limit antibiotic use in a time where "antibiotic stewardship" is increasingly important.

The push to limit antibiotic use must be balanced against the devastating consequences of CNS infection. The low velocity of nail gun projectiles may still have the capacity to drive contaminants into the brain when compared with high-powered firearms referenced in previous studies. Accordingly, our group sides with the current standard-of-care recommendations for penetrating head trauma that include intravenous co-amoxiclav, or intravenous cefuroxime followed by metronidazole for up to 5 days.[18,19]

Antiseizure Prophylaxis

The use of antiepileptic drugs to prevent seizures following penetrating TBI remains a highly debated topic. The incidence of early (within 1 week of injury) PTSs is 6 to 10% and can increase up to 53% in those with penetrating head injury.[20–22] In this comprehensive review, five patients suffered seizures following their injuries; however, there was only one report of a seizure within the 1-week timeframe. Early PTS is predictive of the development of late PTS and eventual epilepsy development. Other risk factors linked to subsequent seizure activity include focal neurologic lesions, hematoma development, and retained metal fragments—the latter playing a potential role in the present case.[23,24] Thus, it appears care providers must consider both surgical intervention and an antiepileptic medication. A 2017 set of recommendations from the Surgical Critical Care Guidelines Committee suggests antiseizure prophylaxis only in those

Table 2 Recommendations

Diagnostic and treatment recommendations for intracranial nail-gun injury
Imaging
CT scan ± CTA if vascular injury is suspected (neurologic deficits, nails deep to calvarium, etc.)
Surgical approach
• Case-dependent • Craniotomy with surgical removal of nails is most common • If nails are located deep in the cortex, consider leaving in place to avoid further injury
Antibiotic prophylaxis
IV co-amoxiclav 1.2 g q8h, or IV cefuroxime 1.5 g, then 750 mg q8h + metronidazole 500 mg q8h for 5 days
Antiseizure prophylaxis
• Levetiracetam for 1 week • Long-term maintenance dose of levetiracetam in those with retained nails

Abbreviations: CT, computed tomography; CTA, computed tomography angiography; g, grams; IV, intravenous; mg, milligrams; q8h, administer every 8 hours.
Note: The above recommendations are based on the cumulative evidence presented through the various case reports that were included in our group's literature review.

with severe TBI, which includes patients with evidence of a brain contusion, intracranial hematoma, loss of consciousness, posttraumatic amnesia for more than 24 hours, or a GCS of 3 to 8.[25] In such cases, the group recommends a week-long course of antiepileptics to prevent early PTS. Late PTS prophylaxis is not recommended as there is no evidence to suggest that continued medication use after this 1-week window would be beneficial in the prevention of posttraumatic epilepsy. The antiepileptic drug used varies based on institutional and physician preference. The most widely used options are phenytoin, as used in the case reported here, and levetiracetam. Given its preferable side-effect profile and because it does not require monitoring of serum levels, levetiracetam is favored in many settings.

Similar to the use of antibiotics for penetrating injury, there is a dearth of published evidence to support or refute the use of antiepileptic drugs in the setting of head trauma. Our recommendations agree with those of the Surgical Critical Care Committee: anyone who suffers a brain contusion, intracranial hematoma, or presents with a GCS of 3 to 8 should receive prophylactic levetiracetam for 7 days. We also suggest the consideration of long-term use of antiepileptics in any situation where metal fragments are retained within the deep brain parenchyma, as in the current case.

Conclusion

Herein we present the case of a patient who suffered penetrating head trauma due to self-inflicted nail gun injuries. This case is significant for being both the most nails reported within a patient's head at presentation and the most nails left in a patient's head after surgery. In review of this patient's course, and the literature concerning penetrating cranial nail gun injury, our group proposes a concise and regimented approach to such patients (►**Table 2**). First, surgery should always be a consideration for the penetrating head trauma patient as the benefits of surgery can be multifold. Of paramount importance is to ensure closure of any blood–brain barrier violations and to address any existing vascular injury that could potentially lead to future hemorrhage or pseudoaneurysm formation. Importantly, this case is evidence that even a semi-conservative approach to nail removal can lead to positive neurologic outcomes. We further recommend the use of a short course of prophylactic broad-spectrum antibiotics and antiepileptic medication, with extension of the antibiotic and antiepileptic medication course for those patients with retained nails or debris.

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None.

Conflicts of Interest
None declared.

Statement of Ethics
Written informed consent was obtained from the patient's parent for publication of this case report and any accompanying images.

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