

Survival after multiple nail gun injuries to the brain, lung, and heart: a case report and a review of the literature

Journal of International Medical Research
49(10) 1–10

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DOI: 10.1177/03000605211049923

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Abstract

Most nail gun injuries involve the extremities and result from work-related accidents. Injuries to the brain or thorax are relatively rare, and cases with injuries to both regions are even rarer and often lethal. Initial evaluation, resuscitation, and surgical planning can be challenging for emergency physicians and surgeons. We present the details of a man with multiple nail gun injuries to the brain, lung, and heart following a suicide attempt. The patient presented to the emergency department in shock. After immediate resuscitation, emergent sternotomy, and subsequent craniotomy, he was discharged without significant morbidity. According to the literature, this is the only reported case involving multiple nail gun injuries to the brain, lungs, and heart. The mortality rate of multiple nail gun injuries involving the head and chest is approximately 20%. Rapid evaluation, immediate resuscitation, and appropriate imaging and surgery are crucial for increasing survival and achieving a good prognosis. Emergency sternotomy for cardiac injury is the foremost priority, and the timing of craniotomy depends on the patient's vital sign status and whether brain injury is evident.

A preprint of this article is available online: DOI: 10.21203/rs.3.rs-35448/v1.

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Keywords

Nail gun injury, penetrating injury, brain, heart, lung, suicide attempt

Date received: 22 May 2021; accepted: 9 September 2021

Introduction

Nail gun penetrating injuries are not uncommon while working, and they occur frequently in the extremities. However, nail gun penetrating injuries can be lethal when they involve vital organs, such as the heart or brain. Such injuries are rarely reported, and concomitant nail gun penetrating injuries to the head and chest are even rarer.¹⁻⁴ Although nail gun injuries are associated with better outcomes than other penetrating injuries caused by knives or bullets, emergency surgery and critical care may still be required.⁵ Here, we present a case of nail gun penetrating injuries to the lung, heart, and brain after an intentional self-harm attempt. The challenge with multiple nail gun injuries to the head and chest is that they cause complicated and urgent conditions that require appropriate orders of imaging and treatment. Through this case, we share our experience and strategies, and we review the related literature.

Case presentation

A 39-year-old man with a history of drug abuse attempted intentional self-harm with a pneumatic nail gun by shooting himself multiple times in his left anterior chest and the right side of his head. After the attempt, he complained of a headache and chest pain, and he reached out to his mother for help. When his mother took him to the emergency department (ED), he was conscious (Glasgow coma scale score: E4V5M6) with a normal respiratory rate (RR) of 18 breaths/minute, tachycardia

(155 bpm), mild hypotension (blood pressure: 94/63 mmHg), and peripheral arterial oxygen desaturation (arterial oxyhemoglobin saturation [SaO₂]: 92%). One visible nail head was found within the right temporal area (Figure 1a), and three were found in the left chest (Figure 1b) approximately 2 cm above the left nipple.

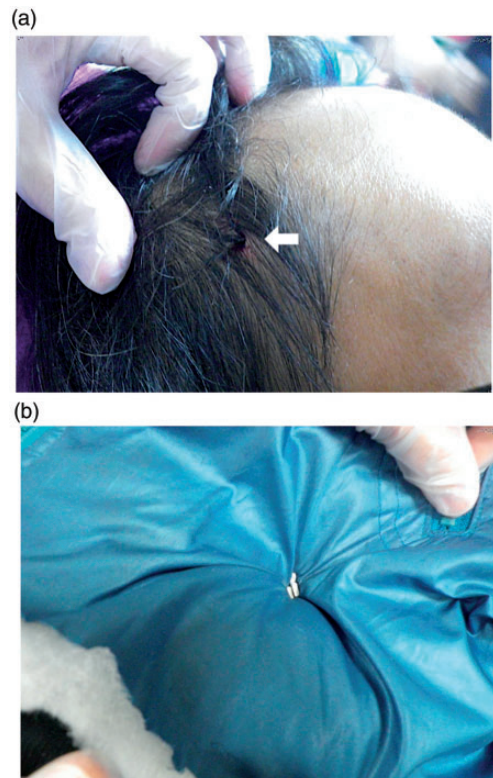


Figure 1. (a) Photograph of the nail penetrating the patient's right temporal bone (arrow); (b) Photograph of the nails penetrating the patient's clothes on the left chest.

The trauma protocol was initiated immediately to provide immediate treatment and resuscitation. Focused assessment with sonography for trauma (FAST) examination revealed pericardial effusion. Whole-body computed tomography (CT) revealed three metallic nails penetrating the left lower anterior chest wall through the lung to the heart, with significant hemopericardium, mild pneumothorax, and moderate hemothorax (Figure 2a). Brain CT showed one metallic nail that had punctured the

right temporal bone without intracranial hemorrhage (ICH) (Figure 2b). After consulting with a cardiac surgeon, chest surgeon, and neurosurgeon, emergency surgery was arranged.

Via a median sternotomy, the cardiac surgeon opened the pericardium to identify two rupture sites on the left ventricle (LV) adjacent to the left anterior descending (LAD) artery bifurcation. Each rupture wound was repaired using pledgeted 4-0 Prolene sutures (Ethicon Inc, Somerville, NJ, USA) (Figure 3). During a sternotomy approach to remove three 5-cm-long steel nails, through-and-through penetration of the left upper lung lobe was noted, and wedge resection was performed by the chest surgeon. Copious normal saline irrigation was performed after the heart and lung repair. Postoperatively, the patient was admitted to the surgical intensive care unit for further resuscitation.

Eight hours after being admitted to the ICU, the patient's hemodynamic status was stable under constant sedation, without the need to administer vasopressors or antiarrhythmic agents. After initiating valproic acid to address focal seizures, we performed a craniotomy around the nail in the right temporal bone (Figure 4a). The nail puncture hole in the brain was contiguous with two branches of the superficial cerebral vein

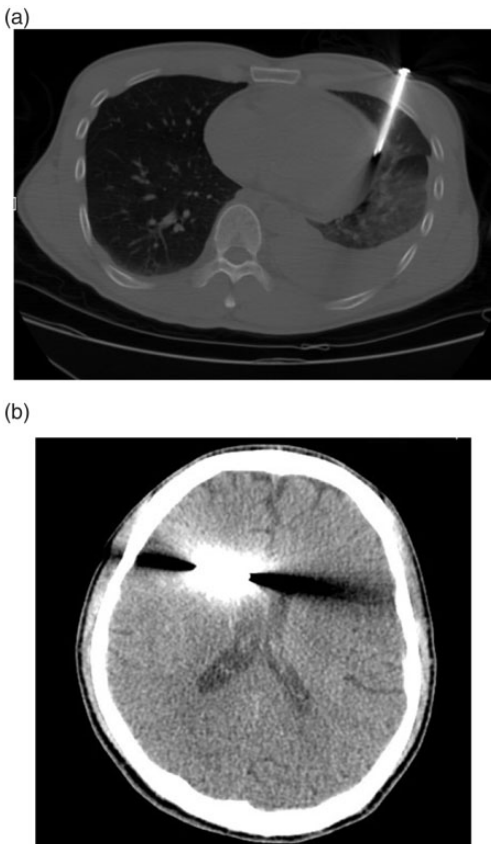


Figure 2. (a) Chest computed tomography (CT), axial view, revealing multiple metallic nails penetrating the lung and pericardium into the LV, causing hemopericardium and hemothorax; (b) Brain CT, axial view revealing a metallic nail penetrating through the right temporal bone into the brain, without evident intracranial hematoma.

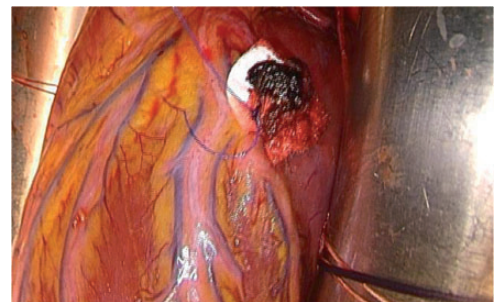


Figure 3. Intraoperative image showing two rupture sites on the left ventricle (LV) adjacent to the left anterior descending (LAD) artery bifurcation, repaired using one pledgeted suture.

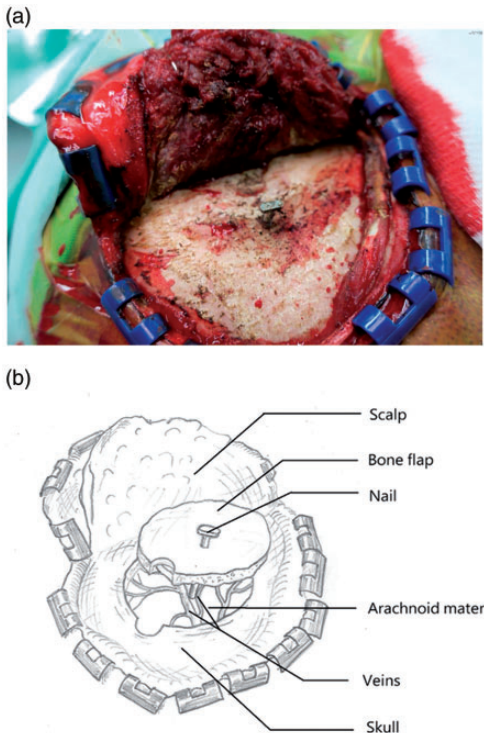


Figure 4. Eight hours after admission to the intensive care unit, the patient's hemodynamic status was stable under constant sedation, without administering vasopressor or anti-arrhythmic agents. We performed a craniotomy around the nail in the right temporal bone (a). Diagram showing that the nail puncture hole in the brain was contiguous with two branches of the superficial cerebral vein (b).

(Figure 4b); however, no vessels were injured by the nail. There was mild oozing from the brain after removing the nail, without a significant hematoma. Postoperatively, levetiracetam was added to the valproic acid to address recurrent focal seizures. The patient was extubated on postoperative day 1 and was transferred to the general ward on postoperative day 3, fully conscious. In the general ward, the patient's vital signs and consciousness level remained stable. Limb weakness, dysphagia, dysarthria, or arrhythmia were not

observed. We consulted the psychiatric department to obtain drug abuse evaluation for the patient, and consulted social workers for discharge planning. Fourteen days after transfer to the general ward, the patient was discharged. At the 2-month follow-up after discharge, the patient had achieved 100% of his baseline performance, without cognitive, motor, or respiratory symptoms.

The study protocol was approved by the Institutional Review Board of Chang Gung Medical Foundation (approval number: 20200947B0). We have obtained consent from the patient to publish this report. The reporting of this study conforms to the CARE guidelines.⁶

Discussion

Nail gun injury

Nail guns have become widely used since the 1980s. Along with the increased productivity, nail guns are associated with increased injuries.^{7,8} The reported rate of injuries related to pneumatic nail guns in the United States was approximately 5000 cases per year between 1991 and 1993, and the number increased to as high as 15,000 cases per year between 2001 and 2003.⁸ Most of the reported injuries appear to be related to unintentional nail gun discharge or misfire.⁹ Although the majority of nail gun-associated injuries are puncture wounds to the extremities, reports of cases involving the chest or torso are increasing, especially for self-inflicted wounds.^{10,11} Intentional self-harm attempts with nail guns are usually fatal.¹²

The projectile speed of a nail gun ranges from 150 ft/s (45.7 m/s) (pneumatic nail gun) to 1400 ft/s (426.7 m/s) (powder-actuated tool).⁵ The former delivers less energy, while the latter has been reported to have similar ballistic parameters and injury potential to those with conventional

firearms.⁹ Injuries related to pneumatic nail guns are more common than injuries from powder-actuated nail guns, most likely because the former are more widely used owing to accessibility and low cost.⁸ Overall, nail gun injuries have better outcomes than other penetrating injuries, such as those caused by firearms.⁵ However, there have been several reports of fatal penetrating nail gun injuries.^{4,11,13}

Penetrating intracardiac injury

Mortality rates for thoracic penetrating injuries vary widely depending on the penetrating object. The mortality rate of nail gun penetrating injuries to the heart is up to 25%, while that of stabbing injuries to the heart is 22% to 62%; gunshot injuries have a higher mortality rate of 60% to 95%.^{5,11,14-16} Potentially life-threatening injuries require a rapid diagnosis to guide management. In our case, the patient's vital signs improved rapidly after resuscitation with crystalloids and blood transfusion despite the initial shock status. Head and chest CT was performed promptly after resuscitation, and we observed hemopericardium, left hemothorax, and at least two metallic nail tips within the pericardial space (Figure 2a). Bedside sonography has been suggested as the first-line evaluation for suspected cardiac penetrating injuries;¹⁰ however, the accessibility of CT makes it an essential part of initial patient assessment.¹⁷ Furthermore, CT is the best method for evaluating penetrating head injuries. CT can also provide information for surveying the penetrating tract, planning surgical procedures, and predicting outcomes.⁴ In patients with atherosclerosis, coronary artery injuries may be detected on CT scans, appearing as calcified patches, and this may facilitate the prediction of surgical findings.⁴ Our patient did not have atherosclerosis.

When a penetrating injury involves the heart, sternotomy and thoracotomy can be performed.¹⁰ If the patient's vital signs are relatively stable, or the patient responds to resuscitation, median sternotomy in an operating room is preferred. If the patient's vital signs are unstable in the ED, resuscitative thoracotomy may be performed in the ED. Right ventricular (RV) injuries are often reported in penetrating cardiac injuries.¹¹ Panicker et al. reported a pledgeted purse string method for simultaneous closure of the RV wound while removing the nail.¹⁰ In our case, the patient's heart injuries involved the LV, which cannot be directly observed during a median sternotomy. LV injuries are also difficult to repair owing to the higher intraventricular pressure and more severe hemopericardium.⁴ In our patient, it was necessary rotate the heart and remove the nail before we could repair the penetrating wound with pledgeted sutures. We did not perform cardiopulmonary bypass during the surgery because the patient had a penetrating brain injury. Postoperatively, the patient's heart rate should be monitored closely for possible arrhythmia. In previous reports, some patients required amiodarone or other medication to stabilize the cardiac rhythm.^{4,10} Our patient did not require such medication because he did not develop an arrhythmia.

Penetrating lung injuries

Generally, penetrating lung injuries with pneumothorax or hemothorax may be treated initially with tube thoracostomy. If there is a persistent air leak or extensive or retained hemothorax, surgery should be considered. In our case, we extended the sternotomy wound into the left pleural space after cardiac muscle repair, and identified a mild laceration in the left upper lobe that was not actively bleeding. Wedge resection was performed, and after the

procedure, no air leak was detected by a water immersion test.

Penetrating brain injuries

Most patients with intracranial nail gun injuries present to the ED with clear consciousness, and the mortality and morbidity rates are low, likely because of the low velocity and energy of the penetrating nail, as mentioned above.^{18,19}

Unlike the thorax, survey imaging of penetrating injuries to the head requires CT to identify the location of the nail, ICH, and fragments.^{17,20–22} However, significant artifacts are frequent, as in our case (Figure 2b). If the nail is close to major vessels, cerebral angiography is recommended to rule out vascular injury.¹⁷ Additionally, the angiography results serve as a baseline for later post-traumatic pseudoaneurysms or fistulas, as stated in multiple reports.^{23–26}

Craniotomy and blind retrieval can be used to remove intracranial nails. Although blind retrieval can be used to remove nails with heads outside of the skull,^{17,27,28} complications, including delayed ICH, have been reported in several studies.^{17,27–31} Therefore, craniotomy is strongly recommended for debridement and hematoma examination in cases of embedded nails.

Regardless of the surgical method, close intracranial pressure monitoring is recommended after surgery.³² The most common postoperative complications after penetrating brain injuries are infection and epilepsy. The infection rates range from 55% to 90% within 3 and 6 weeks, respectively.³³ Owing to the high infection rate, prophylactic tetanus immunization and broad-spectrum antibiotics should be initiated as early as possible.^{22,32,33} In contrast, the prevalence of epilepsy after penetrating brain injuries is approximately 30% to 50%, which is significantly higher than the

rate associated with blunt brain injuries, which is 1.5% to 27%.²² Prophylactic anti-epileptics are recommended to prevent early post-traumatic epilepsy,^{32,34,35} however, their duration is controversial regarding preventing late post-traumatic epilepsy. In our case, we prescribed valproic acid before craniotomy owing to focal seizures. After craniotomy, levetiracetam was also administered owing to recurrent focal seizures.

Ideally, surgery should be performed within 12 hours for penetrating brain injuries if there is no obvious mass effect or active bleeding indicating the need for emergency surgery.^{22,36–38} In our case, emergency sternotomy was indicated owing to the suspected LV rupture, hemo-pericardium, and shock. Our patient did not have neurological symptoms or imaging evidence of ICH that may have progressed rapidly. Therefore, we performed a sternotomy, admitted the patient to the ICU for close monitoring, and arranged for craniotomy after the patient was stabilized.

To date, only five cases of multiple nail gun injuries to the head and chest (including this report) have been reported, and each case presented with different injuries and experienced different outcomes (Table 1).^{1–4} The mortality rate in these five cases was 20%. Albuali et al. reported a case involving three and two nails penetrating the brain and the heart, respectively. Brain CT revealed only minimal subarachnoid hemorrhage (SAH), without a mass effect. Emergent sternotomy and cardiomyotomy was initially arranged, and craniotomy was performed several days later; only a mild complication persisted, postoperatively.³ Pniel et al. reported a case of four nails penetrating the skull with pontine hematoma and one nail within the pericardium. The authors initially removed the nail within the pericardium to minimize the immediate risk of death. After the cardiac surgery, angiography and venography were used to preoperatively plan for intracranial

Table 1. Characteristics of reported cases of multiple nail gun injuries simultaneously to the head and chest.

Authors	Injured organ(s)	Clinical presentation	Operation	Outcome
Sasaoka et al.	Brain, neck, and lung	Three nails penetrating the lung without penetrating the heart Two nails penetrating the brain without massive cerebral hemorrhage One nail penetrating the cervical canal at the C1 level	Emergency surgery to remove nails in the chest, neck, and head	Left hemiparesis and hypalgesia
Albuali et al.	Brain and heart	One nail penetrating the RV and one nail penetrating the LV with hemopericardium and hemothorax Three nails penetrating the brain with minimal SAH	Sternotomy and craniotomy Craniotomy a few days after sternotomy and craniotomy	Right frontalis muscle palsy
Pniel et al.	Brain and heart	One nail within the pericardium with hemopericardium	Surgery to remove the pericardial nail	Mild brain ischemia Infarction with mild left hemiparesis
Ye et al.	Brain and heart	Four nails penetrating the brain and skull base, with pontine hematoma One nail penetrating the LV, with hemopericardium	IJV balloon occlusion Subsequent craniotomy Sternotomy and craniotomy	Death
Current case: Wang et al.	Brain, lung, and heart	One nail penetrating the brain, with ICH and SDH Three nails penetrating the lung into the LV, with hemopericardium and hemopneumothorax One nail penetrating the brain without ICH	Sternotomy and lung wedge resection Subsequent craniotomy	No complications

RV: right ventricle; LV: left ventricle; SAH: subarachnoid hemorrhage; IJV: internal jugular vein; ICH: intracranial hemorrhage; SDH: subdural hemorrhage.

nail removal. One nail pierced the internal jugular vein (IJV), and temporary balloon occlusion was performed before removing the nail. When the patient was discharged, only a mild left hemiparesis persisted.¹ Ye et al. reported a case involving nail gun injuries to the LV and the brain with significant ICH. Emergency sternotomy was performed to repair the LV rupture sites with off-pump coronary artery bypass to preserve cerebral perfusion just before emergency craniotomy. However, the patient did not recover consciousness and eventually died because of end-stage renal disease (ESRD) and severe brain injuries.⁴

Emergency sternotomy or thoracotomy for cardiac injury is the foremost priority; hypovolemic and cardiogenic shock should be controlled first. The timing of craniotomy depends on the extent of brain injury and the patient's vital signs. If brain injury is evident, concomitant sternotomy or thoracotomy and craniotomy by two surgical groups is recommended. If the brain injury is mild, craniotomy may be delayed until the patient's vital signs are stable.

Conclusion

Although multiple nail gun injuries to vital organs are rare, their lethal consequences cannot be underestimated. This is the only reported case of a patient with concomitant nail gun injuries to the brain, lung, and heart who survived without sequelae. Rapid evaluation, immediate resuscitation, and appropriate imaging and surgery are crucial in such cases. If the patient's vital signs are relatively stable, we recommend emergency CT to guide diagnosis and surgical planning. Emergency sternotomy or thoracotomy for cardiac injury is the foremost priority. The timing of craniotomy depends on the patient's vital sign status and whether brain injury is evident.

Acknowledgment

The authors thank Pei-Rong Wu, a member of the CGMH trauma registry databank, for her support during data collection.

Declaration of conflicting interest


The authors declare that there is no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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