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Ultrasound in Emergency Medicine

BEDSIDE ULTRASONOGRAPHY IN THE MANAGEMENT OF PENETRATING CARDIAC INJURY CAUSED BY A NAIL GUN

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☐ **Abstract—Background: Injuries from nail guns are a unique type of penetrating trauma seen in emergency departments (EDs), rising in prevalence in the United States. These devices can lead to life-threatening injuries that require rapid diagnosis to help guide management. Case Report: An elderly man was brought to the ED having sustained a nail gun injury to the chest. After loss of pulses, brief closed chest compressions and rapid blood product administration led to a return of spontaneous circulation. Using bedside ultrasound, a metallic foreign body was identified tracking through the right ventricle with associated pericardial fluid and pericardial clot. This rapid diagnosis with bedside ultrasound helped facilitate timely transport to the operating room for median sternotomy, foreign body removal, and pledgeted cardiac repair. Why Should an Emergency Physician Be Aware of This?: With continued developments in image quality and acquisition, and improvements of physician operator performance, ultrasonography has continued to make significant impacts in traumatically injured patients in new ways. We present this case report to highlight precordial nail gun injuries and to emphasize the diagnostic capabilities of bedside ultrasound for these patients.** © 2018 Elsevier Inc. All rights reserved.

☐ **Keywords—ultrasonography; trauma; heart; nail gun; emergency medicine; thoracotomy; pericardial effusion; cardiac tamponade**

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INTRODUCTION

Since the 1960s, when nail guns were introduced and gained popularity in the workplace, reports of injuries have expanded and continue to be studied (1). Though the majority of nail gun-associated injuries are puncture wounds to the extremities, there are increasing numbers of reports of chest or torso injuries (2–6). Specifically, there have been several reports of penetrating nail gun injuries to the heart, leading to patient presentations varying from asymptomatic to death from exsanguination and cardiac tamponade (3,7). As the number of reports of nail gun injuries increase, so does the number of management options, including temporizing pericardiocentesis, anterolateral thoracotomy, longitudinal pericardotomy, and median sternotomy in the operating room (8). One consistency among case reports is the necessity of rapid recognition and diagnosis of these injuries.

CASE REPORT

A 70-year-old man with a medical history of hypertension was transported by private vehicle to a Level I trauma center shortly after telling his wife that he had accidentally shot himself in the chest with his framing nail gun. The patient was reported to be conversing comfortably with his wife in the vehicle and stated that he became dizzy while working, falling on the nail gun.

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The patient became less responsive as they were arriving to the Emergency Department (ED). He was removed from the vehicle by triage staff and assisted with bag-valve-mask ventilation for poor respiratory effort. The patient was brought immediately into the resuscitation bay and the trauma team activated.

Upon arrival to the trauma bay, the patient rapidly decompensated, leading to respiratory failure and cardiac arrest. The penetrating injury was noted to the anterior chest wall, with the nail partially visible in the cardiac box (9). Closed chest compressions were initiated during preparation for emergent resuscitative thoracotomy. High-flow venous access and blood product administration by mass transfusion protocol were simultaneously initiated with orotracheal intubation.

While preparations for ED thoracotomy were being made, the patient had return of spontaneous circulation with clearly palpable pulses on assessment. The penetrating injury was again noted at the midline of the sternal xiphoid junction. A focused assessment with sonography for trauma (FAST), using a Zonare ZS3 (ZONARE Medical Systems Inc., Mountain View, CA) with a curved 1-4-Mhz probe, was initiated to evaluate the nature and extent of his injuries.

An initial subxiphoid cardiac view was obtained, showing the presence of a pericardial effusion (Figure 1).Further details could be noted, including the presence of pericardial clot (Figure 2), no free fluid below the diaphragm or around the left lobe of the liver, as well as the lack of a penetrant track through the liver. A foreign body with metallic ring-down artifact was noted penetrating through the right ventricular free wall directed toward the septum, but not entering into the left ventricle. There was suspected incomplete cardiac tamponade due to rapidly accumulated pericardial blood and clot with resultant hypotension and, ultimately, cardiac arrest. However, the mid portion of the right ventricle (RV)was free of collapse due to the presence of the nail, which impaired contraction while preventing diastolic collapse (Video 1, available online).The remainder of the FAST examination was not performed to expedite transport to the operating room for median sternotomy and cardiac repair.

The patient was emergently taken to the operating room and underwent median sternotomy with a coordinated repair by Trauma and Cardiothoracic Surgery. Intraoperative transesophageal echocardiogram performed by the cardiac anesthesiologist confirmed no ventricular septal defect. A pledgeted purse string suture was placed around the penetrating wound noted to the free wall of the RV. As the nail was withdrawn, the injury was simultaneously closed. A second injury site along the right ventricular wall, that was felt to be a non-full-thickness cardiac injury, was also repaired.

The postoperative course was complicated by atrial flutter, for which the patient was started on amiodarone by Cardiology. He also had transient episodes of urinary retention and acute kidney injury, both of which resolved with supportive measures. The patient was successfully discharged to a rehabilitation center and walked out of the hospital 9 days after initially presenting in cardiac arrest with a penetrating wound to his heart with a framing nail.

DISCUSSION

The patient was critically ill from his penetrating injury. However, the hemodynamic collapse was more transient than expected. Based on the ultrasound examination, this is suspected to have been due, in part, to the presence of the nail in the RV. The impaired contraction of the RV by the nail also prevented full compression of the RV from the pericardial clot, likely adding some protection from refractory hemodynamic collapse. This allowed more time for stabilization and treatment interventions for the patient's nail gun injury.

One of the largest reviews of nail gun injuries involved those treated in hospital EDs between 2001 and 2005. During these years, the estimated average number of work-related nail gun injuries was 22,200. In this study, 90% of injuries involved the extremities, with the remainder of the injuries being in other regions (5). When the injury involves the thorax, specifically precordial with penetration of the heart, the majority of reported injuries are of the RV (7). Mortality varies widely, depending on the nature of nail gun injuries, although one case series suggested the mortality rate to be close to 25%. For comparison, reported mortality rates from gunshot or stab wounds range from 60–93% and 22–62%, respectively (3).

Although penetrating injuries from nail guns are compared with gunshot or stab wounds, there are inherent differences due to the nature of the injury and causative penetrating object. Many early reports in medical journals reporting on nail gun injuries did not differentiate between the two types of these tools, powder-actuated tool (PAT) and the much more readily available pneumatic nail gun (PNG). PATs utilize explosive charges to propel fasteners into concrete or metal at speeds up to 1400 ft/s. The more common nail gun, PNG, utilizes a much slower velocity of approximately 150 ft/s to drive nails into wood (10,11).This is compared with the muzzle velocity of a bullet, which may range from 700 ft/s in a handgun to over 4000 ft/s in a high-powered rifle (12). Low-velocity stab wounds from a knife, on the other hand, may range from 20–35 ft/s based on the motion of the attack (13).

With the increasing prevalence of nail gun injuries, so too have the number of case reports and described methods of management. Although the vast majority of these injuries occur in the adult population, children may also be affected. Kulaylat and colleagues describe a 29-month-old girl who suffered a self-inflicted

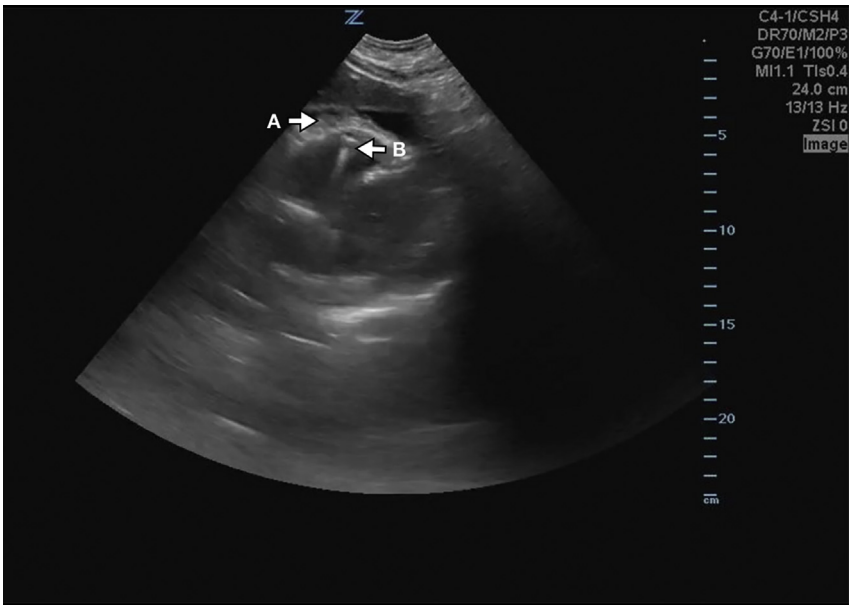

Figure 1. Initial subxiphoid view showing the presence of pericardial clot (A) and echogenic foreign body (B).

penetrating cardiac injury from a nail gun (4). Despite being hemodynamically stable, a median sternotomy demonstrated pericardial effusion with right ventricular injury. In cases when the patient is unstable, ED pericardiocentesis has also been described as a temporizing measure after penetrating nail gun injury (8). After recognition of a penetrating cardiac nail gun injury, the most widely accepted treatment option is surgery, typically sternotomy or thoracotomy (2–4,8).

Despite the planned method of treatment, there are several consistencies regarding management of penetrating cardiac injuries from nail guns. The high risk of mortality of these injuries necessitates rapid diagnosis. Penetrating injuries to the cardiac box—a region of the anterior thorax bounded superiorly by the clavicles, laterally by the midclavicular lines, and inferiorly by the costal margins, have a high associated risk of cardiac wound (9).This type of injury demands need for a high

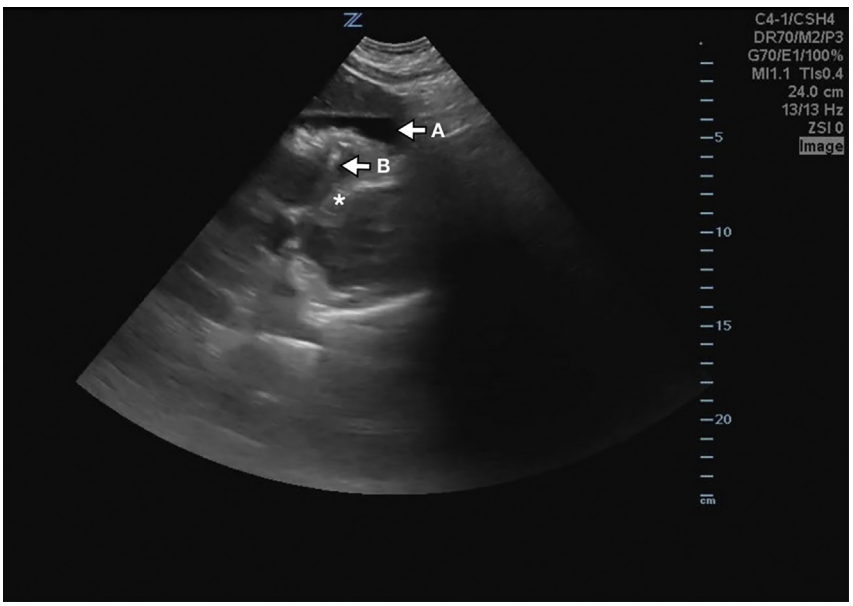

Figure 2. Subxiphoid view showing no free fluid below the diaphragm or around the left lobe of the liver, as well as the lack of a penetrant track through the liver. Pericardial effusion (A) and the echogenic foreign body (B) are noted with the deep end of the foreign body sitting against the interventricular septal wall (*).

level of clinical suspicion and anticipation of timely ED thoracotomy if arrest occurs, or rapid transit to the operating room for exposure by sternotomy or thoracotomy in a nonarrested patient. Closed chest compressions with retained penetrating foreign bodies should not be performed, as this could potentially worsen cardiac injuries and could represent a potential risk to providers performing chest compressions. As was detailed in the case of the patient presented here, injury diagnosis was made through use of point-of-care ultrasound. No other imaging was obtained prior to definitive treatment in the operating room. The critically unstable nature of the patient required highly coordinated efforts between the ED, Trauma service, and Cardiothoracic Surgery in expediting management.

This unusual case presentation is yet another point of evidence highlighting the necessity of combined efforts between multiple services for critically ill trauma patients. Bedside ultrasonography diagnosed this patient's injury within seconds and helped guide this patient's hospital course significantly. With continued improvements in image quality and acquisition, and the increasing availability of experienced physicians, bedside ultrasonography continues to become an increasingly important tool in rapid diagnosis and disposition.

WHY SHOULD AN EMERGENCY PHYSICIAN BE AWARE OF THIS?

Though rare, penetrating injuries to the heart from nail guns require rapid diagnosis and careful management. The presentation may vary from asymptomatic to arresting in the field. A careful history and physical examination, as well as judicious use of imaging studies, is needed given the low prevalence and spectrum of illness. In the case presented here, the patient suffered traumatic cardiac arrest, though he was discharged from the hospital neurologically intact just a few days later. This occurred through rapid diagnosis in the ED with sonography and carefully coordinated treatment through Emergency Medicine, Trauma Surgery, and Cardiothoracic Surgery.

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SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jemermed.2018.09.036.

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