Case Reports

Low-Velocity Nail-Gun Injuries to the Interventricular Septum:

Report of Two Cases, One in a Child

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Nail-gun injury to the heart is rare. Nail-gun injury to the interventricular septum is rarer: we could find only 5 reported cases, and none involving a child. We report 2 additional cases, in which nails penetrated the interventricular septum without causing acute pericardial tamponade, heart block, or shunt across the septum. Transesophageal echocardiography provides a dynamic way to evaluate the patient preoperatively, intraoperatively, and postoperatively.

In the cases reported here, both the adult with multiple interventricular nails and the child with a single nail underwent foreign-object removal via median sternotomy. The child needed cardiopulmonary bypass for removal of the nail. There were no short-term or long-term sequelae from these interventricular septal injuries. ***(Tex Heart Inst J 2015;42(4):393-6)***

Key words: *Adenosine; construction materials/nail gun; echocardiography, transesophageal; foreign bodies/ultrasonography; heart injuries/diagnosis/surgery; interventricular septum; suicide, attempted; wounds, penetrating/surgery*

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Nail-gun injury to the heart is rare. Nail guns usually cause injuries to the extremities. To the best of our knowledge, there have been only 5 reported cases of penetration of the cardiac interventricular septum (IVS), and none of those has involved a child.[1-5]

We describe 2 additional cases of nail-gun injuries through the IVS. One case involved an accidental self-inflicted wounding of a child, who needed removal of the nail during cardiopulmonary bypass (CPB). In the adult, we used adenosine to slow the heart rate in order to extract 3 nails before performing a median sternotomy to suture entrance wounds in the right ventricle (RV). All nails were removed under transesophageal echocardiographic (TEE) guidance.

Case Reports

Patient 1

In March 2012, a 3-year-old Russian immigrant picked up a pneumatic nail gun and accidentally shot himself in the chest. He walked over to his mother and reported that his chest hurt. His mother noticed a small puncture wound in the left parasternal area and took him in the family car to a local emergency department.

Vital signs on arrival were a systolic blood pressure of 128 mmHg, a heart rate of 128 beats/min, a respiratory rate of 20 breaths/min, and pulse oximetry of 98% on room air. Physical examination produced normal results except for a small left parasternal puncture wound in the 5th intercostal space. A portable chest radiograph revealed a nail 3.81 cm in length, penetrating the left chest and possibly entering the left atrium (Fig. 1). The patient was transferred to our trauma center.

Upon arrival, the boy was taken directly to the operating room. The patient showed no clinical signs of pericardial tamponade. Under general anesthesia, he underwent an intraoperative TEE, which showed the nail traversing the mid RV, crossing the ventricular septum, and entering the left ventricular (LV) chamber. The tip of the nail lay adjacent to the LV free wall and limited the movement of the mitral valve cord apparatus, causing mild mitral regurgitation. There was a suggestion of a patent foramen ovale.

Through a median sternotomy, we performed a pericardiotomy and removed a small amount of dark blood. The head of the nail was not visible. Using two 6-0 Prolene traction sutures, we probed the epicardial entry wound; the nail was too

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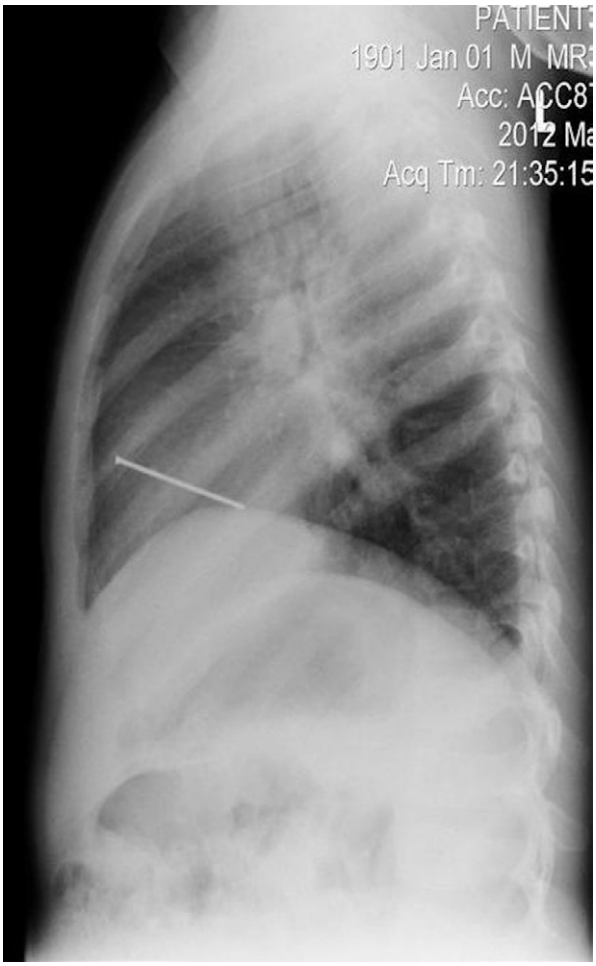

Fig. 1 *Patient 1. Chest radiograph (lateral view) shows the position of the nail in the left hemithorax, penetrating the heart.*

embedded in the myocardium to enable us to grasp the head for removal.

We then placed the patient on cardiopulmonary bypass (CPB) and cooled him to 34 °C. Ventricular fibrillation was induced. We made a small incision over the nail-entry site in the right ventricle, 7 mm from the left anterior descending coronary artery (LAD). The nail was easily extracted. The small right ventriculotomy was closed in a linear fashion with use of a double layer of 6-0 Prolene suture.

We made a small right atriotomy to look for a patent foramen ovale and found only a slit-like irregularity in the atrial septum. The right atriotomy was then closed with 2 layers of running 6-0 Prolene suture.

We discontinued the fibrillator and administered a single countershock to convert the patient to sinus rhythm. He was then rewarmed and weaned from CPB.

After CPB, the TEE showed no evidence of mitral regurgitation or residual ventricular septal defect. The sternotomy was closed with interrupted #1 wire for the sternum and with running coated VICRYL® suture (Ethicon, a Johnson & Johnson company; Somerville, NJ) for the soft tissue, in 3 separate layers; Dermabond® (Ethicon) was applied to the skin. The patient spent one day in the pediatric intensive care unit, where extubation took place. He was administered amoxicillin-clavulanate, along with prophylaxis for diphtheria, pertussis, tetanus, and diphtheria toxoids. A follow-up transthoracic echocardiogram (TTE) showed normal intracardiac anatomy and a trace of mitral valve regurgitation with paradoxical ventricular septal motion. The patient was discharged from the hospital on the 4th postoperative day. Examination of the child (supplemented by echocardiography) on a follow-up office visit 1 month later yielded normal results.

Patient 2

In October 2010, a 37-year-old mental health worker with a history of chronic depression used a pneumatic nail gun to purposely inject 3 nails (each 8.25 cm in length) into his chest, along the left parasternal border. At the scene, he was noted to be awake and alert but subdued, with stable vital signs and no external blood loss. Emergency medical technicians established 2 peripheral 16G intravenous catheters, provided oxygen by nasal cannula, and transported the patient.

On arrival at our trauma center, the patient was taken directly to the operating room because of possible cardiac injuries. He was stable en route, alert and talking, but reporting chest pains. The results of physical examination were normal, except for the 3 nail heads indenting the skin along the left sternal border. The patient's vital signs on arrival were a blood pressure of 113/77 mmHg, a heart rate of 67 beats/min, a respiratory rate of 16 breaths/min, a Glasgow coma score of 15, and a pulse oximetry reading of 100% on 4 liters of oxygen (via nasal prongs). A supine chest radiograph showed no hemopneumothorax. A 12-lead electrocardiogram showed ST-segment elevation in the precordial leads. His cardiac troponin levels were slightly elevated.

We placed a Foley catheter as the trauma anesthesiologist performed rapid-sequence intubation, followed by mechanical ventilation. Bedside ultrasonography showed some pericardial fluid but no evidence of tamponade physiology. Right internal jugular vein and left radial arterial lines were placed. Transesophageal echocardiography revealed mild-to-moderate pericardial fluid accumulation and 2 nails crossing the RV and the IVS, into the LV. Computed tomographic scout images showed possible subdiaphragmatic injuries caused by the inferior nail (Fig. 2). Three-dimensional reconstruction was performed to show the exact location of the 3 nails with respect to cardiac structures, diaphragm, and liver (Fig. 3).

We administered adenosine intravenously, to slow the heart to a rate of 30 beats/min. All 3 of the nails were removed with an Allis clamp, timed with the cardiac cycle. A median sternotomy, with extension to an upper-

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Fig. 2 *Patient 2. Computed tomographic scout image (lateral view) shows the positions of the nails that are penetrating the patient's heart. Note also the subdiaphragmatic injuries.*

midline laparotomy, was then performed. We retracted the sternal edges and performed a pericardiotomy, revealing a moderate amount of blood in the pericardium. Two small holes in the RV next to the LAD and vein exhibited pulsatile bleeding and were repaired with pledgeted 3-0 Prolene sutures. The 3rd nail had not entered the pericardial sac. The heart was rotated to confirm the absence of injuries to the lateral, inferior, and posterior walls of the left ventricle. On TEE, there were no residual ventricular septal defects.

An exploratory laparotomy revealed a small hole in the anterior stomach, near the cardia, which was repaired with a 3-0 Prolene suture. The lesser sac was opened, and no injuries were found in the posterior wall of the stomach. There was a graze injury on the inferior aspect of the left lobe of the liver.

There was no indication for a pleural tube, because there was no pleural entry. A Blake drain was placed in the pericardium. The sternotomy and the abdominal incisions were closed.

In the intensive care unit, the patient was given epidural analgesia for pain management and was extubated. A sitter watched over him. After 2 days, he was moved to the acute care floor. His slightly elevated troponin levels on admission returned to normal. Five days postoperatively, he was transferred to the psychiatric unit.

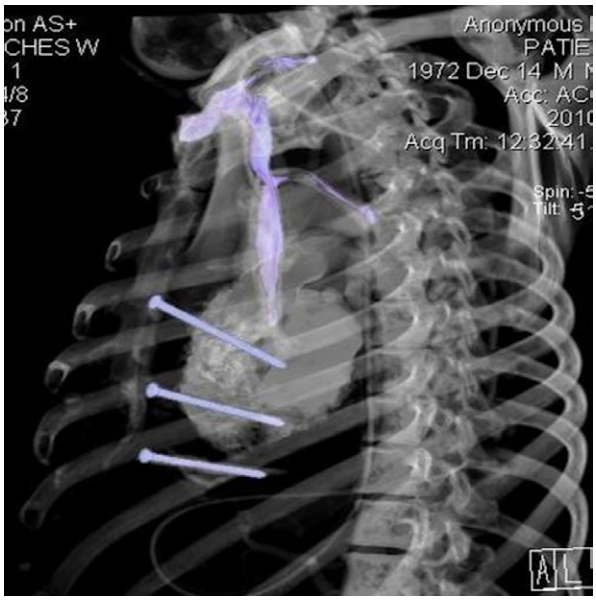

Fig. 3 *Patient 2. Computed tomogram (3-dimensional reconstruction) shows the penetration of 2 nails across the ventricular septum.*

Discussion

Nail guns or stud guns were introduced to the construction industry in the 1950s. These tools were made to propel nails or steel bolts into wood, concrete, or steel in rapid succession to increase the speed and efficiency of construction workers.

There are 2 basic types of these tools[6]: one uses an explosive charge as an energy source, and the other uses compressed air. The explosive-charge tools are called power-actuated tools (PATs) and have a velocity that ranges from 96 to 395 m/s. These are used for concrete- or metal-fastening work. Pneumatic nail guns (PNGs) are lower-velocity tools that are commonly used in the house-construction industry, for wood framing and roofing.

These tools can cause severe damage to the human body, depending on what structures they penetrate. The reported 25% mortality rates associated with nail-gun injuries are similar to the mortality rates from stab wounds, which range from 22% to 62%.[1] There are no current data on the difference between PAT and PNG injury patterns. The Centers for Disease Control states that the PATs are far more likely to cause disabling or even fatal injuries.[6]

Nail-gun injuries to the heart are rare, and injuries to the IVS are extremely rare. The earliest article that we found about nail-gun injuries was published by Marti in France, in 1955[5]; he also was the first to report a cardiac IVS injury by a nail gun. In the United States literature, Mage and Szu, in 1962, were the first to report a nail-gun injury,[7] and the first reported nail-gun injury to the cardiac septum did not appear here until

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1999.[1] Since then, only 3 American cases involving the IVS have been published.[2-4] In 1964, Zverev[8] reported (in Russian) one case of nail-gun injury to the heart of a child.

Conclusion. Both of our patients presented in hemodynamically stable condition, without evidence of cardiac tamponade. This gave us time to evaluate each thoroughly and to plan the appropriate surgical intervention. Echocardiograms are instrumental in seeing the course of the nail penetration in the heart and in evaluating cardiac function before and after nail removal.

Transesophageal echocardiography revealed that nails limited myocardial motion in the involved portion of the heart, but they did not impair contractility in the rest of the myocardium.

Sternotomy with retraction of the sternal edges might displace embedded nails and cause larger tears in the myocardium and septum. Preoperative preparations for an immediate sternotomy are prudent during nail removal. The use of intravenous adenosine to slow the heart rate and decrease myocardial contractility enables the surgeon to extract the nails embedded in the chest wall, thereby reducing the risk of tears in the heart. Continuous TEE seems to offer the best way to evaluate the technique and timing of nail removal from a cardiac chamber or septum without causing harm.

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