

Case Illustrations of the Utility of Echocardiography in Gunshot Wound Trauma



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INTRODUCTION

Among trauma victims, cardiovascular injuries are the second most common cause of death after central nervous system injuries.¹ Cardiac trauma is divided into two broad categories: nonpenetrating or blunt cardiac injuries and penetrating cardiac injuries. Blunt cardiac injuries are more common and occur due to motor vehicle accidents and crush injuries. Penetrating cardiac injuries are due to stabbing and gunshot wounds (GSWs) and carry higher mortality.¹ In GSWs to chest or abdomen, a bullet can cause direct injury to the cardiac structures and result in tamponade, structural cardiac defects, or valve or aortic injury.²⁻⁴ Rarely, patients present with bullet embolization, which can be venous or arterial. A peripheral venous entry of the bullet can terminate in the right atrium or right ventricle or embolize to the pulmonary circulation.⁵ Abdominal gunshot injury with traumatic aortocaval fistula can also lead to bullet embolization to the right ventricle.⁶ Paradoxical emboli enter the arterial circulation from the venous system, right atrium, or right ventricle, through an intracardiac defect such as a patent foramen ovale or a ventricular septal defect.⁶ Entry of the bullet to the left heart can embolize to the cerebral circulation, and entry into descending aorta may be entrapped in the wall or present with embolization to the peripheral arteries.⁷⁻⁹ The standard of care in evaluating traumatic GSW injuries includes contrast material-enhanced computed tomographic angiography (CTA) and bedside ultrasound.^{10,11} Artifacts from bullets can obscure the pathway or exact positioning of the bullet on CTA, and echocardiography becomes a valuable imaging modality when the heart is involved.^{12,13} We present two cases of cardiac gunshot injuries in whom transthoracic (TTE) and transesophageal echocardiography (TEE) played a key role in precise bullet localization and guidance during surgery.

CASE PRESENTATIONS

Case 1

A 17-year-old male patient with no significant medical history presented with a GSW close to the right scapula. On presentation,

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the patient was normotensive, but tachycardic to 110 beats per minute, and his respiratory rate was 24 breaths per minute. Physical examination was significant for a wound of bullet entrance near the right scapula but no wound of exit. The right-sided chest tube, which had been placed in the emergency department, was noted. The lungs were clear to auscultation, and no murmur was noted. Chest CTA done in the emergency department revealed the bullet entry from right upper lobe of the lung, passing through the mediastinum to settle in the region of the proximal descending thoracic aorta (DTA; [Figure 1](#)). Significant metallic streak artifact from the bullet, however, limited evaluation of the precise location and magnitude of injury to the aorta ([Figure 1](#)). The patient was clinically stable, so it was suspected that the bullet had not penetrated any vascular structures. In consultation with the cardiothoracic surgeon, a TEE was performed to determine the exact location of the bullet. On TEE imaging, it was found to be lodged in the wall of the DTA, 2 cm below the left subclavian artery ([Figure 2](#), [Videos 1 and 2](#)). An aortogram confirmed no active blood extravasation ([Figure 3](#)). The patient subsequently underwent surgical removal of the bullet and repair of the aorta ([Figure 4](#)).

Case 2

A 19-year-old male patient with no significant medical history presented with a GSW to the left side of his abdomen with extensive vascular injury. On presentation, he had heart rate of 103 beats per minute, blood pressure of 78/54, and saturation of 98% on 2 L/minute of oxygen. Physical examination revealed no heart murmur. He had an acute abdomen with severe pain and a left flank laceration. He had a wound of bullet entrance in the left flank but no wound of exit. Abdominal computed tomography (CT) revealed aortocaval fistula, but no bullet was noted in the abdomen. Computed tomography scan of the abdomen and chest showed a bullet in the cardiac shadow ([Figure 5](#)). He underwent emergent laparotomy, during which surgeons discovered a 1.5 cm perforation in the right lateral aspect of the abdominal aorta, an infrarenal aortic pseudoaneurysm, and an aortocaval fistula, which was repaired.

While recovering and stable in the inpatient unit, a bedside TTE was performed ([Figure 6](#)). Transthoracic echocardiography with three-dimensional imaging located the bullet under the septal leaflet of the tricuspid valve ([Figure 6](#), [Videos 3 and 4](#)). During surgery for bullet extraction, intraoperative TEE revealed that the bullet was not present in the location seen by previous TTE. It was suspected that it had migrated to the right ventricular outflow tract (RVOT) beneath the pulmonary valve but was not clearly visualized. Therefore, the aortic cross clamp was placed to occlude the main pulmonary artery and prevent the bullet from passing distally into the pulmonary arteries. At surgery, the bullet was recovered from the RVOT. We suspect this bullet embolized from the aortocaval fistula into the RV and eventually migrated to the RVOT ([Figure 7](#)).

VIDEO HIGHLIGHTS

Video 1: Long axis of proximal DTA at 25 cm from the incisors with the bullet in the posterior wall of the aorta.

Video 2: Long axis of proximal DTA at 25 cm from the incisors with color flow imaging. The bullet in the posterior wall of the aorta.

Video 3: Transthoracic apical four-chamber two-dimensional view with left ventricle on viewer's left showing the bullet under the tricuspid valve.

Video 4: Transthoracic apical four-chamber three-dimensional view with apex down orientation showing the bullet under the tricuspid valve attached to the posterior right ventricular wall.

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DISCUSSION

Gunshot injury and bullet embolization are extremely rare and confined to case reports or case series. In a patient with GSW, the presence of only entry point and lack of exit wound should raise the suspicion for bullet embolization. Bullet embolization can be arterial or venous. Arterial emboli are more often symptomatic, presenting

with peripheral embolization and symptoms of limb ischemia. The majority of venous emboli eventually migrate to the right ventricle or pulmonary arterial tree.¹⁴ In a review of 261 cases from the literature published over 30 years, Kuo *et al*¹⁴ reported roughly equal involvement of the right and left circulation. We present two cases of bullet embolization in whom TTE and TEE played a key role in precise bullet localization and surgical management. In the first case the bullet was entrapped in the DTA and posed a risk of bullet migration with acute aortic rupture. The second case presented with traumatic aortocaval fistula resulting from GSW to the abdomen and bullet embolization to the right ventricle. This presentation is extremely rare.⁶ In both our cases, there was no time delay after the gunshot injury, and they were brought to the emergency department right after trauma. Computed tomography imaging studies done on initial presentation showed the bullet to be in the cardiac shadow. TTE and TEE were done later for precise localization of the bullet.

Contrast-enhanced CTA is the current initial standard of care for patients with GSWs with suspected vascular injury.^{10,11} Hanpeter *et al*¹⁰ determined that helical CT angiography accurately visualizes the gunshot trajectory and reduces the need for invasive angiography. In a meta-analysis of 892 trauma patients with extremity injuries, Jens *et al*¹¹ demonstrated that patients who are hemodynamically stable can safely undergo CTA to diagnose vascular injury. Metallic objects such as bullets can, however, cause artifacts in the radiographic image, which can prevent accurate diagnosis of location and trajectory of the bullet (Figures 1 and 5). Although CT imaging is the most useful initial imaging modality, the most accurate imaging test to localize intracardiac

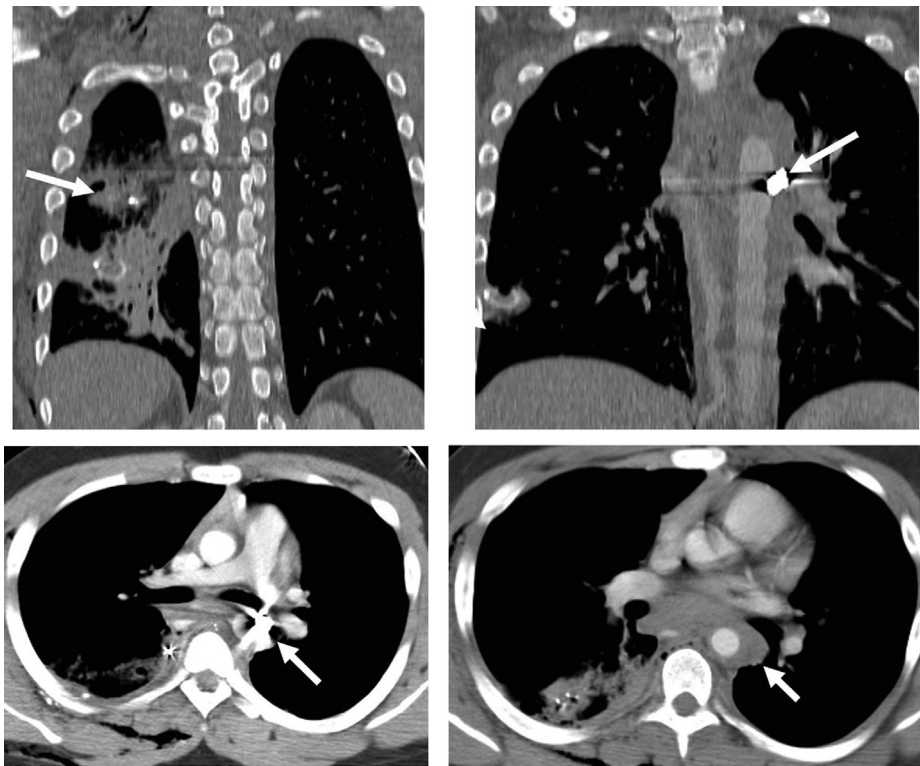


Figure 1 Noncontrast CT of the chest in coronal projection. The *left upper panel* shows the bullet entrance through the right upper lobe of the lung (*arrow*). The *right upper panel* shows the entrapment of the bullet in the proximal descending aorta (*arrow*). Contrast-enhanced CTA of the chest in the *bottom left panel* in axial projection shows bullet with artifact in the region of DTA (*arrow*), and in the *bottom right panel* shows mediastinal hematoma around DTA (*arrow*).

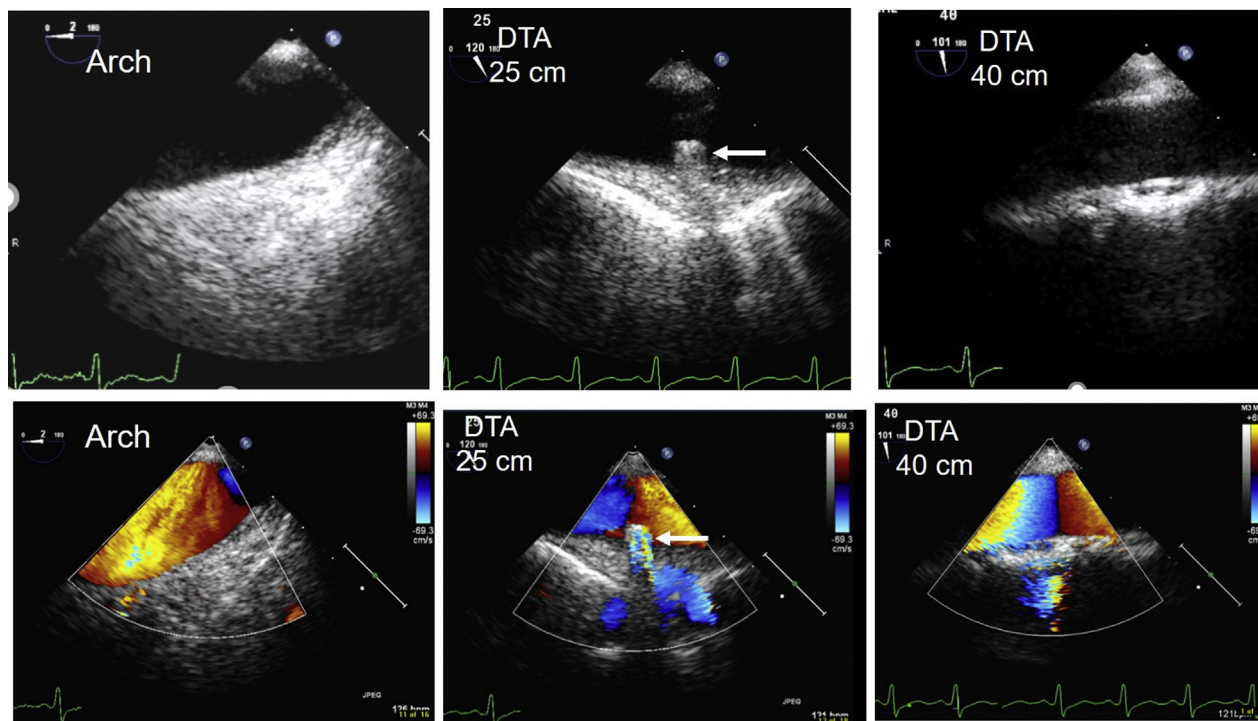


Figure 2 Examination of aortic arch and DTA by TEE. Left upper and lower panels show TEE images of normal arch without and with color. Middle upper (without color) and lower panel (with color) show the long axis of proximal DTA at 25 cm from the incisors. The bullet is entrapped in the posterior wall of the aorta (arrow), and thickening of the aortic wall is suggestive of intramural hematoma. The right upper and lower TEE images without and with color show normal distal DTA at 40 cm from incisors.

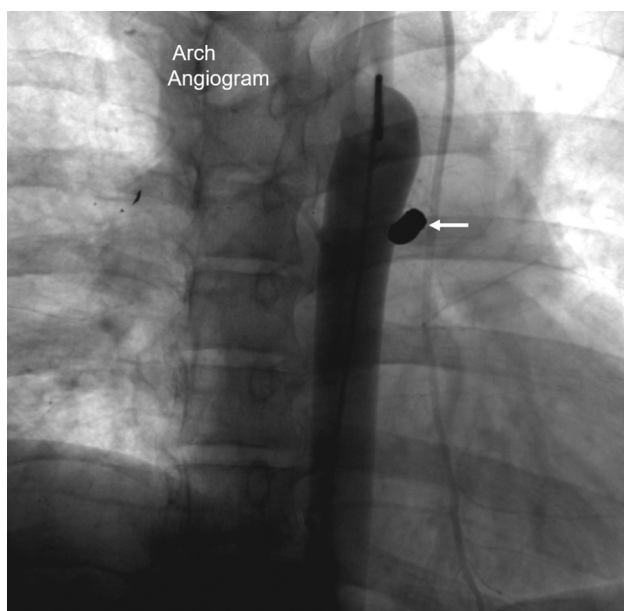


Figure 3 Arch aortogram showing the bullet (arrow) in the wall of the DTA as diagnosed by TEE.

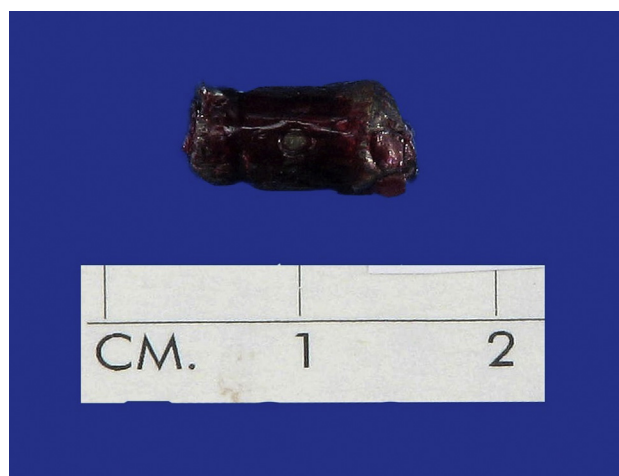


Figure 4 Bullet removed at surgery from the DTA.

missiles and plan further management is echocardiography.^{12,13} Hyperechoic appearance of the pellets is characteristic on echocardiographic imaging. A retrospective review of TEEs performed in 16 mediastinal penetrating injuries by Mollod and Felner¹³ revealed subtotal

aortic disruptions and intracardiac projectiles and shunts otherwise not clearly diagnosed on other imaging modalities. In our first case, CTA images showed mediastinal hematoma around the DTA suggestive of aortic injury, but the location of the bullet within the wall could not be determined due to artifacts (Figure 1). The TEE images clearly show the intramural hematoma of the aortic wall and the bullet entrapped in the wall of the DTA (Figure 2, Videos 1 and 2). In the second case the CT images show the bullet to be in the right heart (Figure 5), but TTE images are convincing for entrapped bullet in the right ventricle (Figure 6, Videos 3 and 4). These anatomic details

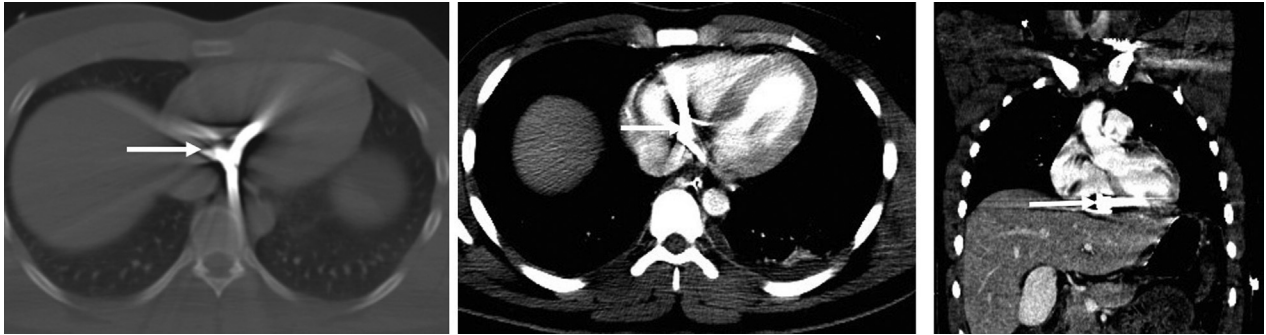


Figure 5 CT images of chest without contrast (*left*), axial projection with contrast (*middle*), and coronal projection (*right panel*) show the bullet in right heart with considerable streak artifact (*arrow*).

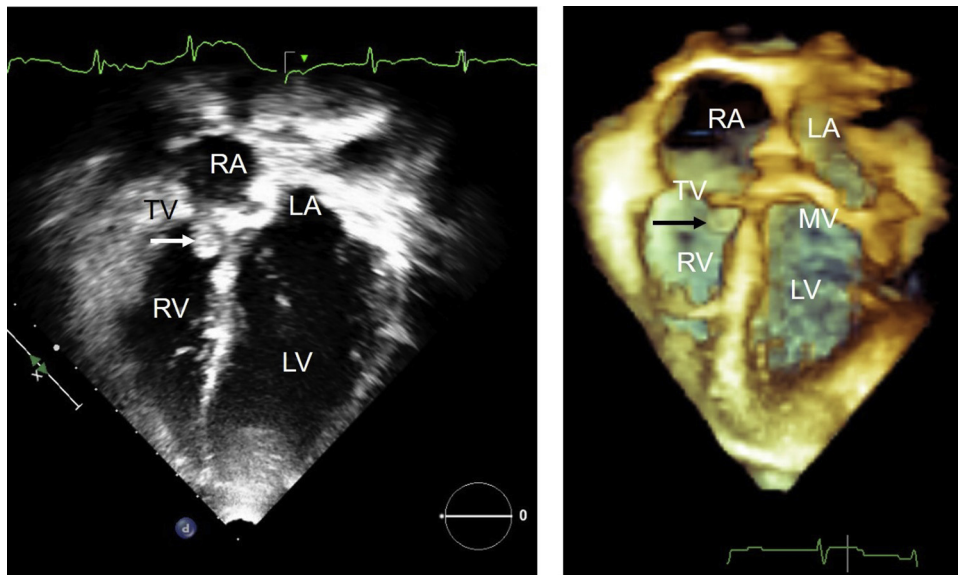


Figure 6 Transthoracic apical four-chamber two-dimensional (*left*) and three-dimensional views (*right panel*) with apex down orientation showing the hyperechoic bullet (*arrow*) under the tricuspid valve (TV) attached to the posterior right ventricular wall (RV). LA, Left atrium; LV, left ventricle; MV, mitral valve; RA, right atrium.

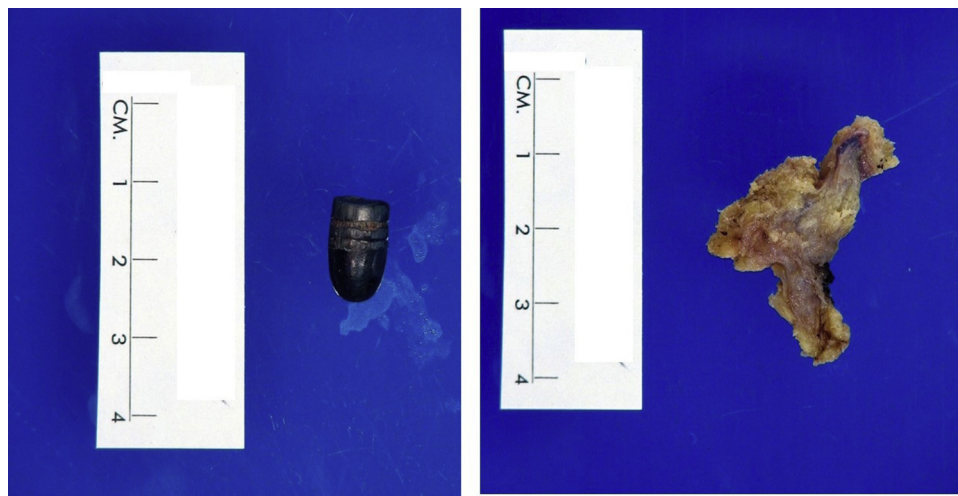


Figure 7 Bullet removed at the time of surgery from RVOT shown in the *left panel*. The *right panel* shows the residual granulation tissue removed from posterior wall of right ventricle under the tricuspid valve where bullet was noted by echocardiography but had moved to RVOT during surgery.

provided by echocardiography in both cases helped the surgeon in making a plan for surgical intervention.

Because of the relative scarcity of bullet embolization, there are no universally accepted management guidelines. High-velocity bullets, as in military firearms, usually traverse through the body tissues and exit. Low-velocity bullets, as in civilian firearms, can lodge in the body tissues and, rarely, in the vascular tree. These cases will have no exit wound and can present with embolization.¹⁵ The treatment depends on the final destination site of the bullet fragment and compromise of adjacent structures and should be individualized. Some studies suggest that all intracardiac emboli should be surgically removed. However, other studies recommend removal of bullet emboli within the right heart only if the bullet fragments cause valvular dysfunction, erosion into adjacent structures, arrhythmia, abscess formation, and pulmonary infarction.^{6,16} Most studies agree on removal of all left-sided bullet emboli. Removal of intracardiac bullet emboli can be performed with open surgical procedure or using endovascular interventional techniques.¹⁶⁻¹⁸ Transesophageal echocardiography can provide intra-procedural guidance, as in our cases.

CONCLUSION

We present two rare cases of bullet embolization. While CTA is the standard of care for initial imaging of most GSWs in trauma centers, determining the exact location within the thorax can be challenging given the streaking artifacts from the bullets. In patients with cardiac involvement, TEE plays a key role in precise bullet localization and guidance during surgery.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.case.2021.08.001>.

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