Retrograde Venous Bullet Embolization to the Hepatic Inferior Vena Cava Located with Intraoperative Transesophageal Echocardiography

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INTRODUCTION
Cardiac trauma following a gunshot wound (GSW) to the chest is a common occurrence. However, it is uncommon for bullet fragments to undergo embolization after a GSW. The majority of bullet fragments embolize in an antegrade pattern, but one study found as many as 15% of 153 cases in which bullets embolized in a retrograde fashion.1 We present a case in which a GSW to the chest led to a retrograde venous bullet embolization. The fragment originated in the right atrium and embolized to the hepatic inferior vena cava (IVC), which was located with intraoperative transesophageal echocardiography (TEE).

CASE PRESENTATION
A 21-year-old African American man with no medical history presented to the emergency department as a level 1 trauma status post GSW to the right posterior thorax with no exit site. Initial presenting hemodynamics included tachycardia and hypotension. The patient reported pain in his right posterior thorax at the site of the penetrating injury, as well as shortness of breath. On physical examination, the patient was noted to have decreased breath sounds in the right thorax. Chest radiography (CXR) revealed a right-sided pleural effusion and right pneumothorax with shrapnel material overlaid the right inferior thorax (Figure 1).

As a result, a right-sided chest tube was immediately placed, which drained 1,000 mL of blood. Heart rate and blood pressure normalized after management of the tension pneumothorax/hemothorax. At that time, the patient was stable to undergo additional imaging via computed tomography (CT) of the chest and abdomen (Figure 2), which revealed a metallic fragment within the right atrium, without other obvious cardiovascular findings.

The patient was then emergently brought to the operating room for right atrial exploration and thoracic IVC repair. General endotracheal anesthesia was induced, and left radial and right femoral arterial catheters and a right internal jugular central venous catheter were inserted. Sternotomy was completed and cardiopulmonary bypass initiated. Anesthetic care consisted of volatile agents, opiates, and benzodiazepines along with crystalloid, blood products (i.e., packed red blood cells, fresh frozen plasma, and platelets) and vasopressor agents. TEE before sternotomy and IVC repair displayed a normal left ventricle in the transgastric midapical short-axis view and was suspicious for IVC or right atrial hematoma, but no intracardiac bullet fragments were identified. After IVC repair, TEE revealed good right ventricular and left ventricular function and a radiolucent particle within the intrahepatic IVC, as seen in Figure 3. This was confirmed with portable intraoperative CXR, as seen in Figure 4.

The patient was weaned from cardiopulmonary bypass, followed by chest closure, as seen in Figure 5 (left). He was then transferred to a hybrid operating suite, where he underwent inferior venacavography, with the successful removal of a 2-cm bullet fragment. Fluoroscopic images demonstrating interventional radiology and vascular surgery removal of the bullet fragment can be seen in Figures 6A and 6B. The patient remained hemodynamically stable throughout the procedure, with hemoglobin never falling below 6.1 g/dL. The patient was then successfully transported to the cardiothoracic intensive care unit, with an estimated blood loss of approximately 300 mL.

Overnight in the cardiothoracic intensive care unit, the patient had a sudden output of roughly 2.5 L of bloody discharge from his right chest tube over the course of 20 min. Cardiothoracic surgery was contacted, and the patient was transfused 6 U of packed red blood cells and 4 U of fresh frozen plasma, 1 U of cryoprecipitate, and one pack of pooled platelets. The patient’s chest was then reopened bedside, but no active bleeders were found. Following the product administration, the patient’s coagulopathy corrected, and chest tube output decreased significantly. The patient’s chest was then packed and remained open overnight, placed to vacuum suction as seen in Figure 5 (right). The following morning, on postoperative day 1, the patient’s chest was closed. Sedation was weaned, and the patient was successfully extubated on postoperative day 2.

DISCUSSION
A patient’s hemodynamics strongly influence operative versus nonoperative management in cardiac trauma secondary to penetrating injuries. CXR and CT provide comprehensive and valuable information regarding the locations of intracardiac fragments. CT is limited, however, as it is not performed in real time. These static images provide great detail with regard to tissue, but because they are not live images, their usefulness in locating an embolizing fragment can be limited. Intraoperative TEE has long been a dynamic diagnostic imaging modality used in the identification of cardiac dysfunction. Additionally, as evidenced in this particular case, it can also be used to assist in locating intracardiac foreign bodies and, with the use of real-time images, can ultimately guide surgical treatment.2

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Currently, there is limited literature on intracardiac fragments with retrograde embolization into the venous system as presented here. This is most likely because the majority of intravascular fragments embolize in an antegrade pattern. As these fragments are projected in the direction of blood flow, however, retrograde movement is an effect of gravity. There are specific signs that should raise suspicion of an embolized fragment in a patient that presents after a GSW, such as when the metallic object has been identified in a different anatomic location from its predicted trajectory path. As mentioned, the majority of emboli are arterial in nature (roughly 80%). Bullet fragments located within the venous system typically migrate to the right atrium and into the pulmonary vascular tree. A review of the literature by Corbett et al. from 1987 to 2010 reported 45 cases of venous bullet emboli. Of these, 22 were lodged in the right heart, 15 within the pulmonary artery, and only two within the hepatic vein. Regardless, both arterial and venous embolizations can result in severe complications. Some of these complications include limb-threatening ischemia, sepsis, endocarditis, cardiac valvular incompetence, pulmonary embolism, cerebrovascular accident, and/or death. The time frame of migration can vary broadly among patients, with symptoms reported up to several years following the initial injury. A literature review conducted by Lundy et al. found a complication rate of 13% for patients with retained right atrial fragments following GSWs. Two specific

**Figure 1** Preoperative portable CXR. Initial CXR during trauma assessment demonstrating a right-sided pneumothorax/hemothorax and shrapnel material overlying the right atrium. Arrow indicates right visceral pleural line.

**Figure 2** Contrast-enhanced coronal CT of the chest, myelogram windows, demonstrating the bullet lying within the right atrium.

**Figure 3** Metallic fragment in hepatic IVC on TEE.

**Figure 4** Intraoperative portable CXR with shrapnel material lying within the hepatic IVC, represented by the blue arrow.
complications included new-onset dysrhythmia and new-onset tricuspid valve regurgitation secondary to valve destruction. Management of a bullet embolization includes surgical removal, endovascular extraction, or a combination of both. The treatment modality is often dictated by the clinical scenario, such as the timing of presentation, location of emboli, and severity of symptoms. The risks and benefits of intervention versus close observation must be examined and tailored to each patient’s particular case. Fewer invasive procedures are now necessary for extraction as endovascular techniques continue to advance.

We present a case in which initial CT imaging located a fragment within the right atrium. Because of deteriorating hemodynamics, including a tension hemothorax, urgent surgical intervention was initiated. Once in the operating room, neither initial TEE nor operative exploration was successful in locating any intracardiac fragments. It was not until after cardiac structures were repaired that reevaluation with TEE identified a radiopaque fragment within the hepatic IVC (Figure 3). This fragment was confirmed with portable CXR. The timing of bullet embolization is difficult to identify and is assumed to have occurred sometime between CT of the chest, abdomen, and pelvis to the induction of general anesthesia with endotracheal intubation.

The mechanism of retrograde intubation is again typically secondary to gravity but can also be influenced by changes in body position, such as transfer from a patient bed to an operating room bed. Another potential mechanism of embolization may have been related to the changes in intrathoracic pressures and right ventricular filling pressures that occur during induction of general anesthesia, endotracheal intubation, and initiation of positive pressure ventilation. These events
would have led to an increase in intrathoracic pressure, particularly right ventricular filling pressures, causing an increase in venous back pressure to the vena caval system. This effect would have been exaggerated in a hypovolemic patient in whom venous return is already compromised, as in this patient’s case. These pressure changes, with suspected patient positional changes, could have led to this retrograde embolization into the hepatic IVC. The alteration in systemic hemodynamics related to cardiopulmonary bypass and nonpulsatile flow was believed to have had little impact on the embolization of this fragment, as the fragment had embolized before initiation of cardiopulmonary bypass.

The ability of TEE to locate this fragment significantly changed the treatment approach, resulting in interventional percutaneous retrieval. Identification with plain radiography alone would not have provided the detail of whether this fragment remained intravascular or had migrated out into the abdomen. This would have resulted in either an exploratory laparotomy or leaving the operating room to obtain further imaging, both having additional risks and complications. Furthermore, TEE is a portable imaging modality with quick access in the intraoperative setting that can assist in the location of these cardiovascular fragments, with the understanding that the use of this modality is operator dependent, favoring those with more experience. Ultimately, the use of TEE can be used to direct surgical treatment options.

CONCLUSIONS

This case highlights one of the several uses of intraoperative TEE. Bullet embolization can make locating and removing any foreign material quite challenging. However, intraoperative TEE played a vital role in locating the bullet fragment using real-time images, guiding both surgeons and interventional radiologists in extraction.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.case.2017.10.003.

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