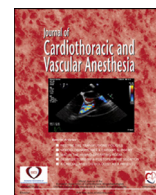




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Case Report

Abdominal Gunshot Causing Ventricular Septal Injury Without Perforation into the Pericardium



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GUNSHOT WOUNDS (GSWs) to the chest and abdomen are common in urban US populations. Penetrating cardiac injury is considered more lethal than other traumatic injuries, with up to 90% mortality before the victim reaches the hospital.¹ Several case reports have documented unusual presentations of GSWs to the chest with heart penetration, including gunshots causing right coronary artery (RCA) occlusion,² penetration of right ventricle by bullet without pericardial effusion,³ and a patient with a GSW to the chest who was diagnosed with a ventricular septal defect (VSD) and developed a third-degree block 3 days after his injury.⁴ However, no cases of intracardiac injury after an intra-abdominal GSW without evidence of heart perforation have been described, to the authors' knowledge. Herein, the case of a 39-year-old male who developed a third-degree atrioventricular block requiring emergency placement of an transvenous pacemaker during emergency surgery for intra-abdominal bleeding after a right flank GSW is described.

Case Presentation

A 39-year-old male presented to the emergency department after experiencing a GSW to the right flank. The primary survey revealed a single entry site in the right flank with no identifiable exit wound. Point-of-care ultrasound revealed fluid in the abdomen and right chest. The patient's condition subsequently became hemodynamically unstable, so 4 units of packed red blood cells were transfused and a right sided chest tube was placed with minimal blood output. A chest x-ray showed a possible intrathoracic location of the bullet. He was taken emergently to the operating room for exploratory laparotomy.

After induction of general anesthesia and placement of vascular access, the patient developed third-degree atrioventricular block and hypotension refractory to atropine and minimally responsive to epinephrine. Transcutaneous pacing was unsuccessful due to poor capture, so a transvenous pacemaker was placed emergently. A limited transesophageal echocardiography (TEE) examination was performed intraoperatively, revealing a grossly normal chamber size and normal biventricular function. Importantly, no pericardial

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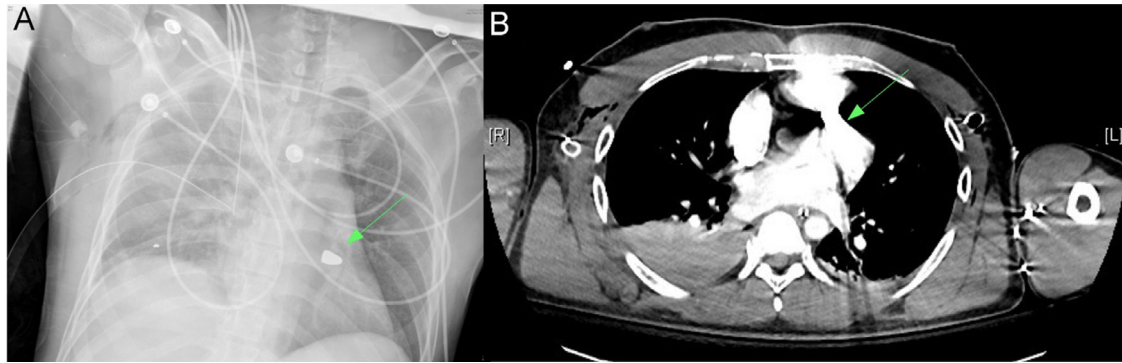


Fig 1. (A) Preoperative chest x-ray revealing a bullet in the chest and (B) a computed tomography scan obtained after exploratory laparotomy revealing the bullet location in the interventricular septum (green arrow).

effusion or other evidence of perforation of a cardiac chamber into the pericardium was identified ([Supplementary Video](#)). The examination was limited due to concerns of the possible mediastinal location of the bullet, observed earlier on the chest x-ray performed in the emergency department ([Fig 1A](#)). Therefore, the TEE probe was removed and an upper esophagogastroscopy was performed to rule out gastrointestinal injury. The patient's condition was hemodynamically stable after placement of the transvenous pacemaker, so after abdominal packing, the decision was made to transfer the patient to the surgical intensive care unit (SICU) with open abdomen for a delayed abdominal closure. Before arrival to the SICU, computed tomography imaging was performed to assess for other injuries. This revealed the previously observed damage to the right kidney and liver, a right hemothorax, and no pericardial effusion. Furthermore, a metallic object with sharp reflection was observed in the interventricular septum ([Fig 1B](#)), which was concerning for an intracardiac location of the bullet.

On arrival to the SICU, the patient's condition was hemodynamically stable, and the patient was off any vasopressor or inotropic support. A comprehensive TEE was performed immediately because of the suspected intracardiac location of the bullet. This again revealed no pericardial effusion or evidence of chamber perforation into the pericardium. However, a VSD was identified in the anterior interventricular septum at the level of the perimembranous septum, in close proximity to the aortic valve ([Fig 2A](#); see [Supplementary Video](#)). The defect demonstrated a left-to-right flow ([Fig 2B](#); see [Supplementary Video](#)) into the left ventricular outflow tract. A congenital VSD usually would present with right ventricular dilation secondary to chronic volume overload. Given the overall normal cardiac anatomy, absence of any other congenital abnormalities, normal right to left ventricular size, and no signs of pressure or volume overload of the right ventricle, this presentation was believed to be a new VSD.

The patient was taken urgently to the cardiac operating room. Intraoperative TEE again confirmed the VSD and furthermore revealed a shunt between the left ventricle and right

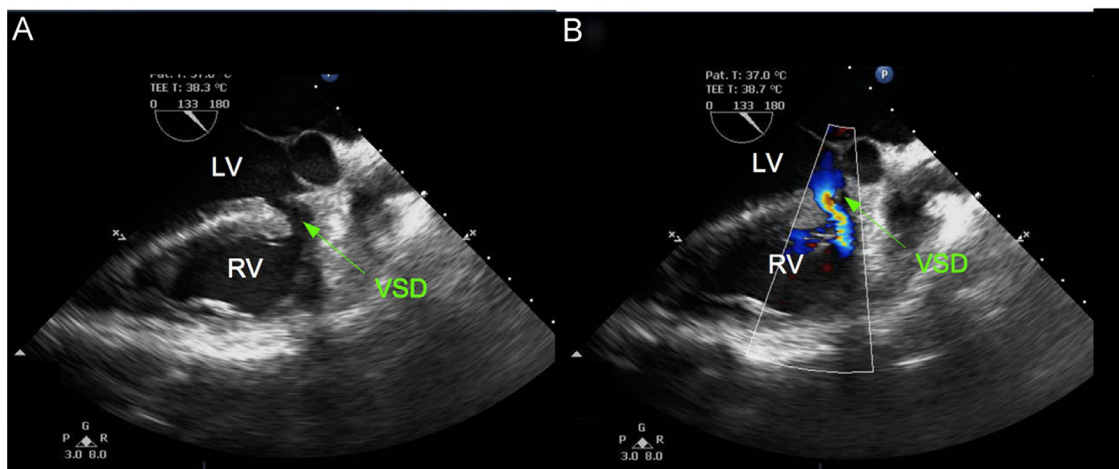


Fig 2. Transesophageal echocardiographic images performed in the intensive care unit after exploratory laparotomy and computed tomography imaging. Shown are (A) the midesophageal long-axis view revealing a ventricular septal defect in the interventricular septum (green arrow) and (B) color Doppler analysis suggestive of a left-to-right flow through the septal defect. See also the [Supplementary Video](#). LV, left ventricle; RV, right ventricle; VSD, ventricular septal defect.

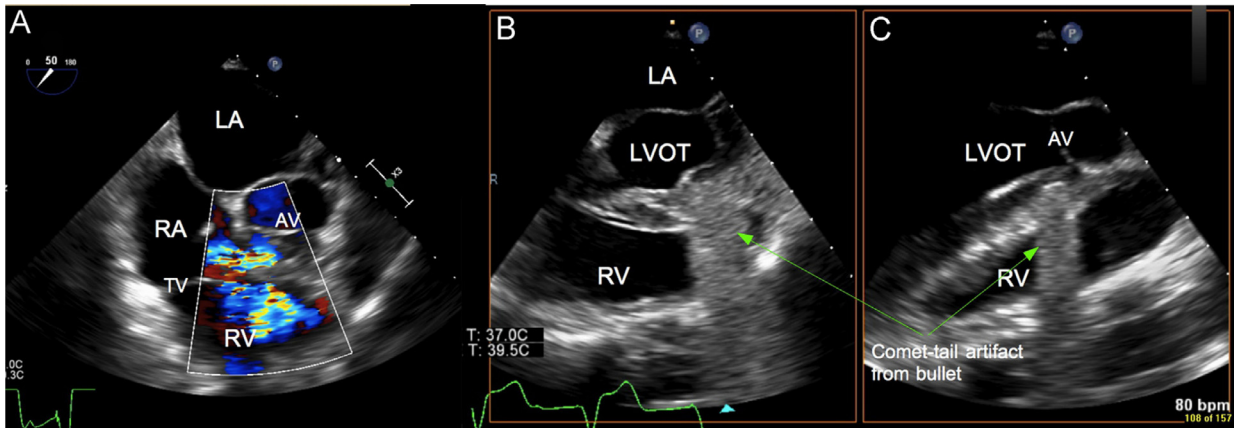


Fig 3. Intraoperative transesophageal echocardiographic images during cardiac surgery. Shown are (A) color Doppler analysis of bloodflow into the right atrium and right ventricle using the with the aortic valve short-axis view revealing a ventricular septal defect and presence of ventriculo-atrial shunt and (B and C) modified x-plane view (biplane) slightly below the plane of the aortic valve, revealing a comet-tail reverberation artifact from the bullet lodged into the interventricular septum (green arrow). See also the [Supplementary Video](#). AV, aortic valve; LA, left atrium; LVOT, left ventricular outflow tract; RA, right atrium; RV, right ventricle; TV, tricuspid valve.

atrium (acquired Gerbode defect). In addition, a perforation in the septal leaflet of the tricuspid valve was observed (Fig 3, see [Supplementary Video](#)). The bullet was found to be lodged in the interventricular septum (Fig 3b and 3c, see [Supplementary Video](#)). After a full sternotomy and systemic heparinization, cardiopulmonary bypass was initiated via single aortic cannulation and bicaval venous cannulation. The surgical examination confirmed the defects identified on the TEE. The bullet could not be found by visual inspection or palpation of the interventricular septum, and the decision was made to not attempt recovery of the bullet to avoid further cardiac injury. Initial attempt at patch repair of the VSD and tricuspid replacement with a 27 mm Mosaic (Medtronic, Minneapolis, MN) bioprosthetic valve resulted in distorted anatomy of the aortic valve and subsequent severe aortic insufficiency, so the aortic valve was replaced with a 19 mm Regent (St. Jude Medical, St. Paul, MN) mechanical bileaflet prosthetic valve. Postoperative TEE examination revealed well-functioning prosthetic valves, good left ventricular function, and global right ventricular dysfunction.

On postoperative day 1 a pacemaker with epicardial leads was placed. On postoperative day 2 the patient underwent coronary angiography because of persistent right ventricular dysfunction, for which a mid 90% RCA stenosis was stented and an intra-aortic balloon pump was placed. A distal RCA branch with complete occlusion was not amenable to stenting. The chest was closed on postoperative day 2. Subsequently the patient had a good recovery, was extubated on postoperative day 9, and was discharged from the SICU on postoperative day 18 and to home on postoperative day 26. He remains in good health.

Discussion

This case presented the challenging diagnostic dilemma of a patient presenting with a single abdominal entry wound and evidence of a right hemothorax and presence of abdominal

fluid. Additional imaging was limited due to hemodynamic instability of the patient, so exploratory laparotomy was deemed appropriate for diagnosis and management. The patient demonstrated further hemodynamic instability at the time of induction of anesthesia with the development of a third-degree heart block, likely secondary to an acute mechanical or thermal destruction of the atrioventricular node by the bullet. Although injuries to the atrioventricular node occur frequently after myocardial infarction or cardiac surgery, they rarely have been described as a complication of either penetrating or blunt trauma to the chest.^{5–7} The generation of an atrioventricular shunt after blunt chest trauma with secondary development of atrioventricular block after repair has been described.⁸

The patient described here was found to have both a VSD and a shunt between the left ventricle and the right atrium (Gerbode defect) through a perforation in the septal leaflet of the tricuspid valve. The diagnosis of VSD was relatively straightforward, given the large jet observed between the right and left ventricles on color Doppler. Additional quantitative information regarding the severity of a VSD can be gleaned from calculation of the ratio of blood flow through the right and left ventricular outflow tracts. However, the calculation of this ratio was not performed because of the large defect observed on 2-dimensional and color-flow Doppler imaging and the limited time available for imaging before institution of cardiopulmonary bypass. A left ventricle–right atrium shunt (Gerbode defect) can present as a congenital abnormality but also can occur after cardiac surgery or myocardial infarction or secondary to endocarditis.⁹ One third of Gerbode defects are supravalvular defects without any additional defects in the tricuspid valve leaflets, and two thirds present with an infra-valvular form, in which blood through a VSD is diverted into the right atrium due to a concomitant defect in the tricuspid valve septal leaflet, as seen in the present case. The diagnosis of a Gerbode defect can be challenging because the jet observed on echocardiography can be mistaken easily for a

tricuspid regurgitant jet, but suggestive findings include a high-velocity jet (>4 m/s) extending into the atrium, normal pulmonary diastolic and systolic pressures, and the presence of both diastolic and systolic jets, without evidence of right ventricular hypertrophy. A diagnosis of acute tricuspid perforation is challenging, and requires detailed imaging of the tricuspid valve from the midesophageal 4 chamber, right ventricular inflow-outflow, and modified bicaval views,¹⁰ and 3-dimensional echocardiography with color-flow Doppler can assist in identifying the leaflet pathology.

Some additional features of this case are worth mentioning. Because of the postoperative hemodynamic instability, a coronary angiography was performed and demonstrated that 2 portions of the RCA were stenosed. Given the multiple locations of RCA disease, it is possible that this was secondary to previously undiagnosed atherosclerosis. However, with the proximity of the entire RCA to the tricuspid annulus,⁹ it cannot be ruled out that the injury occurred during the tricuspid valve replacement.

Surprisingly, the bullet appears to have entered the chest without any evidence of penetration of a cardiac chamber into the pericardium. This was evidenced by the absence of pericardial effusion on the TEE examination performed during the initial evaluation of the patient. A previous analysis of 66 patients found the incidence of pericardial tamponade with cardiac GSWs to be 31% and hemorrhage to be 67%.¹⁰ The generation of the VSD indicates that the bullet still had considerable mechanical energy when it entered the heart, so it likely entered with considerable velocity rather than passive embolization. The bullet lodged in the interventricular septum, completely avoiding chamber perforation into the pericardium. This resulted in the omission of the cardiac injury during the initial abbreviated TEE examination. Although the trajectory of the bullet within the abdomen and chest could not be mapped clearly, the authors believe that the most likely bullet trajectory was through the liver and into the lumen of the inferior vena cava. It then traveled into the right atrium, perforating the septal leaflet of the tricuspid valve, and finally traveled through the interventricular septum and became lodged there.

This case highlights the utility of a thorough evaluation by performing advanced TEE in trauma patients with suspected

intracardiac injury. This is supported by a recent review that demonstrated the incidence of cardiac injury to be greater than previously believed. This review furthermore recommended refraining from using entry into the historical cardiac box as a guide to identify patients at risk for cardiac injury.¹¹ Furthermore, although presumably extremely uncommon, intracardiac injury should be suspected in the appropriate individuals with hemodynamic instability despite a lack of pericardial effusion or evidence of chamber perforation into the pericardium.

Appendix A: Supplementary material

Supplementary data associated with this article can be found in the online version at <https://doi.org/10.1053/j.jvca.2018.02.038>.

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