Bullet Embolization: Multidisciplinary Approach by Interventional Radiology and Surgery

Timothy Nolan, M.D.¹ Ho Phan, M.D.² Andrew Hal Hardy, M.D.¹ Pavan Khanna, M.D.¹
Paul Dong, M.D.¹

¹Department of Diagnostic Radiology

²Department of Surgery, UC Davis Medical Center, Sacramento, California

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Address for correspondence and reprint requests Paul Dong, M.D., Department of Diagnostic Radiology, Cardiovascular/Interventional Radiology, UC Davis Medical Center, 4860 Y street, Suite 3100, Sacramento, CA 95817 (e-mail: paul.dong@ucdmc.ucdavis.edu).

Abstract

Bullet embolization after penetrating trauma is an infrequent but important phenomenon. It presents an unexpected sequelae to the otherwise predictable injury pattern of penetrating missile injury mechanism and poses a challenging diagnostic and therapeutic dilemma. Bullets from penetrating wounds can gain access to the vasculature and migrate to nearly every large vascular bed. Patients can be asymptomatic, but the potential complications can be devastating including limb-threatening ischemia, sepsis, endocarditis, cardiac valvular incompetence, pulmonary embolism, stroke, and even death. The exact incidence of bullet embolization is unknown, but it was estimated to be 0.3% during the Vietnam War and 1.1% in the recent conflict in Afghanistan and Iraq. The scarcity of the condition and the lack of concentrated experience at any single institution contribute to the controversies pertaining to the management approach. Traditionally, surgical extraction of embolized bullets may involve difficult and invasive surgical exposures. Recent advancement in endovascular techniques provides an additional option in this treatment algorithm. In this article, we describe a case of venous bullet embolization from the left iliac vein treated by a combined endovascular and surgical approach.

Keywords

- ▶ penetrating trauma
- ▶ bullet embolization
- ▶ endovascular retrieval
- ▶ interventional radiology

Objectives: Upon completion of this article, the reader will be able to (1) explain the incidence and potential complications of bullet embolization, and (2) recall the challenge of diagnosing this entity and the therapeutic possibilities available including endovascular retrieval.

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Case Presentation

A 46-year-old man presented to a local level 2 trauma center after sustaining a single gunshot wound to the right upper quadrant of the abdomen. The patient was hemodynamically unstable and was taken emergently to the operating room for exploration of the abdomen. He was found to have a through and through injury to the liver, small intestinal injury at two locations, and a single injury to the infrarenal vena cava. The

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Figure 1 (A) Preoperative portable chest radiograph that fails to demonstrate the bullet. (B) Postoperative portable chest radiograph demonstrating migration of the bullet to the upper abdomen (arrow).

injury to the liver was treated with intraoperative packing, the small bowel injuries were sutured primarily, and the injury to the inferior vena cava was primarily repaired. The bullet was not found intraoperatively. Postoperative chest and abdominal radiographs demonstrated that the bullet had migrated cephalad to the retrohepatic cava at the level of the diaphragm (►Figs. 1A and 1B). A computed tomography (CT) scan of the abdomen and pelvis suggested that the bullet was intravascular within the inferior vena cava (IVC) at the junction of the right hepatic vein (►Fig. 2). With concern for venous embolization of the bullet, the patient was subsequently transferred to our medical center the same day for definitive treatment.

Upon arrival, the initial evaluation included a chest radiograph demonstrating the location of the bullet to be unchanged. Because of the proximity of the bullet to the cava-right atrial junction, a two-dimensional echocardiogram was performed. Although limited due to technical difficulties,

the echocardiogram confirmed that the bullet was not intracardiac.

The patient was taken to the interventional radiology suite for attempted endovascular retrieval of the bullet. The right femoral vein was accessed with an 8F vascular sheath through which a 5F pigtail catheter was inserted for venography. The initial venographic images demonstrated that the bullet appeared to reside within the IVC (►Fig. 3). The pigtail catheter was exchanged for a 7F Ensnare device (Merit Medical, South Jordan, UT) and then a 7F Amplatz loop snare device (Covidien, Mansfield, MA). Multiple attempts to snare the bullet with both devices were unsuccessful, even with the patient placed in reverse Trendelenburg position and with Valsalva maneuvering (►Fig. 4). The snare devices were removed, and a 5F Cobra C2 catheter (Cook Medical Inc., Bloomington, IN) was inserted through the sheath and used to select the right hepatic vein. Further venographic imaging still could not definitely confirm the location of the bullet (►Fig. 5). Again, attempts at snaring were unsuccessful with

Figure 2 Contrast-enhanced axial computed tomography scan of the abdomen, bone windows, demonstrating the bullet in the likely location of the inferior vena cava.

Figure 3 Oblique subtracted image obtained during inferior vena cavography demonstrating the bullet within the infrahepatic inferior vena cava.

Figure 4 Unsubtracted oblique image obtained during failed first retrieval attempt.

the snare continuing to move freely in the region of the bullet. At this point, no further attempts were made, and the decision was made to continue to follow the patient clinically.

The patient underwent two more operations for removal of liver packing and closure of the abdomen. On hospital day 14, it was recognized on an abdominal radiograph that the bullet had migrated to the left pelvis; a CT scan confirmed that the bullet was located in the left common iliac vein (**Fig. 6**).

The patient was subsequently taken back to the interventional radiology suite to reattempt endovascular retrieval of

Figure 5 Subtracted image in the posteroanterior projection during hepatic venography, again demonstrating the expected intracaval location of the bullet.

the bullet. The left femoral vein was accessed and an 8F vascular sheath was inserted. Venography was then performed, showing the bullet in the left external iliac vein (**Fig. 7**). A 7F Ensnare device (Merit Medical) was used to successfully capture the bullet (**Fig. 8**). The bullet was shown to move freely attached to the snare device. The patient was then taken to the operating room, where the snared bullet was removed through a left femoral venotomy (**Fig. 9**). The patient did well postoperatively and was discharged hospital day 21.

After retrospectively reviewing this case, we concluded that the bullet had likely embolized from the infrarenal IVC to the retrohepatic IVC, and eventually retracted into the proximal right hepatic vein. Because of this location, snaring maneuvers within the IVC could not contain the bullet. After the patient recovered from shock and with improvement of hepatic venous flow, the bullet migrated back to the IVC and subsequently down to the left iliac vein, presumably due to gravity.

Discussion

Bullet embolization after penetrating trauma is an infrequent but well-described phenomenon. When the bullet enters the vessel, it usually passes through both walls of the vessel. However, in some instances the bullet loses its kinetic energy and remains within the vessel. The bullet usually migrates in the direction of blood flow, but retrograde embolization occurs in up to 15% of patients, and the effect of gravity has been suggested as a cause.¹ The diagnosis of bullet embolization is often difficult, but embolization should be considered in the following scenarios: incongruent number of penetrating wounds without intraoperative or radiographic confirmation of projectiles, the location of the projectile is inconsistent with the missile trajectory, or migration of the projectile with serial radiographs.

The incidence of missile embolization after penetrating injury was reported to be 0.3% in the Vietnam War (of 7500 casualties surveyed), and 1.1% in the Afghanistan and Iraq Wars (of 346 casualties surveyed).^{2,3} The incidence of bullet embolization in the civilian setting is unknown, but it could be higher because of the lower velocity weapons with lower kinetic energy found in the civilian setting. Bullet embolization can be characterized as arterial, venous, or paradoxical. Arterial bullet embolization can result from penetrating wounds originating from the left ventricle, pulmonary vein, thoracic aorta, abdominal aorta, and peripheral arteries. Paradoxical venous embolization, in which the bullet migrates from a venous entry point and ends up in the arterial system, has also been infrequently reported.^{4,5} Bullet embolization into the arterial system generally is symptomatic in 80% of patients, often with end-organ ischemia, and usually discovered early.⁶ Venous bullet embolization can originate in the peripheral veins, neck veins, vena cava, and right ventricle. Although many ultimately migrate to the right ventricle or pulmonary arterial system, some can migrate retrograde due to the effect of gravity.^{1,6} Two thirds of patients with venous embolization are asymptomatic; symptomatic

Figure 6 (A, B) Noncontrast computed tomography scan, bone windows, in the (A) axial and (B) coronal planes demonstrating the bullet in the left common iliac vein.

patients may present late, sometimes months to years after the initial injury.^{6–10}

The lack of concentrated experience at any single institution contributes to the variation in approaches to the management of patients with bullet embolization. The difficulty with establishing a general treatment algorithm is further complicated by the variation in anatomical locations, the timing of presentation, and the presence or absence of symptoms. Patients with arterial or paradoxical emboli are either symptomatic and/or are at tremendous risk for ischemic complications such as stroke and extremity amputation. Generally, most authors agree that arterial bullet emboli should be retrieved as soon as they are recognized. Although venous bullet embolization can be asymptomatic, the complications can be severe. These include cardiac valvular destruction, endocarditis, sepsis, venous thrombosis, thrombophlebitis, dysrhythmia, and severe hypoxia. Therefore, it is

also generally accepted that patients with venous bullet emboli who are symptomatic should undergo extraction of the missile. However, debate continues about the most appropriate management for asymptomatic patients with venous bullet emboli. Kortbeek et al reviewed 32 cases of pulmonary artery bullet emboli from 1966 to 1992 who were successfully managed conservatively.¹¹ These authors advocated conservative management for patients with pulmonary artery bullet emboli. Shannon et al reviewed 102 cases of venous bullet emboli from 1930 to 1987 and reported a 25% overall complication rate.¹⁰ These authors advocated mandatory extraction of venous bullet emboli discovered early (<6 weeks), but they suggested that selective observation in asymptomatic patients with later discovery is acceptable. Another review of 45 cases of venous bullet emboli from 1987 to 2010 revealed 14 of 45 patients (31%) were managed successfully without extraction; 26 cases (58%) were

Figure 7 Subtracted image in the posteroanterior projection obtained during iliac venography demonstrates the bullet in the external iliac vein.

Figure 8 Unsubtracted image demonstrating successful snaring of the bullet.

Figure 9 Unsubtracted intraoperative image just prior to open removal of the bullet. The bullet was withdrawn into the femoral vein where a cutdown could easily be performed. Open arrow shows the snare around the bullet. White arrow shows the vascular clamp placed on the more central femoral vein.

managed with an intervention.⁷ These authors were in favor of extraction of the missile in all patients with intracardiac missiles and observation in select asymptomatic patients with pulmonary arterial emboli. The risk for extraction in the early reports was quite substantial, with many patients requiring thoracotomy, sternotomy, and/or cardiopulmonary bypass. Since the advent of endovascular techniques, more cases of venous bullet emboli are being managed by an endovascular or hybrid approach, combining endovascular with surgical techniques. Anecdotally, endovascular techniques provide a less invasive option for the extraction of venous bullet emboli with minimal comorbidity.

Because of the rarity of the condition, the differences in published opinions, and the multiple factors that go into the treatment consideration, the authors advocate that the management of patients with venous bullet emboli should be individualized. Factors that should be considered include the presence of symptoms, anatomical location of the bullet, suspected contamination and risk of infection, timing of diagnosis, the accessibility of the bullet by endovascular

techniques, the morbidity of the surgical approach, and patient comorbidities.

Teaching Points

- Bullet embolization is a rare phenomenon, but the complications can be devastating and include limb-threatening ischemia, sepsis, endocarditis, cardiac valvular incompetence, pulmonary embolism, stroke, and death.
- Most authors agree that all arterial and symptomatic venous bullet emboli should be extracted, whereas mandatory removal of asymptomatic venous bullet emboli is debatable.
- Therapeutic options for removal of bullet emboli include surgical extraction, endovascular retrieval, or a combined approach.

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