Abdominal Shotgun Wound With Pellet Embolization Leading to Bilateral Lower Limb Amputation: Case Report and Review of the Literature of Missile Emboli Over the Past 10 Years

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Missile embolus is an unusual but recognized complication of gunshot injuries. Originally described in 1834, some 160 cases were reported in 1996.[1] We present a case study of a 17-year-old man with an abdominal shotgun wound who, in addition to serious internal injuries, also sustained pellet embolization of the lower limb arterial supply resulting in bilateral below-knee amputations. A PubMed search (www.ncbi.nlm.nih.gov./ PubMed, 1995 to September 2006) was performed using a combination of the MeSH term foreign body vascular embolism with additional text words (pellet embolism, bullet embolism, missile embolism, and embolectomy). Reference lists of the retrieved literature were manually cross-searched for additional publications. This yielded 45 reported cases. Data from these cases were correlated and compared. Categories analyzed included the patient's age, morbidity and mortality, type of firearm used, the distance of the shooter, the source and destination of the embolus, whether the embolus was venous or arterial, and whether it was anterograde or retrograde. Presenting symptoms were correlated with the arterial or venous nature of the embolus. The nature of interventions was reviewed. Data were tabulated, and simple statistical methods were used for analysis using standard computer software. Based on the presented case and the literature review, recommendations for the diagnosis and management of a missile embolus are made.

CASE REPORT

A 17 year-old man sustained a single close range shotgun wound to the abdomen (Fig. 1). At the scene, he had an evisceration injury, was pale, and had external blood loss estimated to be >500 mL. His airway was patent and protected. He had a respiratory rate of 30 breaths per minute and his chest was clear on auscultation. His systolic blood pressure was 50 mm Hg with a pulse that fell from 115 beats per minute to 90 beats per minute during the 38 minutes between on-scene assessment and arrival in the emergency department. Oxygen saturation was 99% and Glasgow Coma Scale score was 15. In the emergency department, he was intubated and transferred immediately to the operating suite. Intraoperative findings revealed a complete abdominal aortic transection below the renal arteries, pellet injuries to the left and right common iliac arteries, multiple perforations of the colon, and small bowel with gross faecal contamination of the peritoneal cavity. The aortic transection was repaired with a straight graft and the left internal iliac artery and mesenteric bleeding points were oversewn. Peripheral pulses were noted to be present at the conclusion of the procedure. In the ensuing 24 hours, the patient underwent several damage control laparotomies during which total colectomy, splenectomy, multiple small bowel resections, and formation of a gastrojejeunostomy and ileostomy were performed. Within that time, he received 27 units of red blood cells, 16 units of fresh frozen plasma, 8 units of platelets, 18 units of cryoprecipitate, and 2 units of activated factor VIIa.

Twenty-four hours after admission, it was noted that his right foot had become cool and now had absent dorsalis pedis and posterior tibial pulses and an absent doppler signal. The left foot had a normal appearance, but it too was pulseless. Femoral and popliteal pulses were present bilaterally. Plain X-ray film of the limbs showed shot that had embolised into the right leg (Figs. 2 and 3). After intraoperative percutaneous angiography of the lower limbs (Fig. 4), a pellet embolectomy from the right peroneal and posterior tibial artery, embolectomy and thrombectomy from the distal left popliteal artery, and bilateral lower limb fasciotomies were performed. The ischemic changes did not improve significantly necessitating bilateral below-knee amputations 9 days after admission. After a prolonged recovery, the patient was discharged and was able to walk on bilateral below-knee prostheses.

DISCUSSION

Since 1995, 46 cases of gunshot wounds resulting in missile embolism have been reported. Of those, 17 (37%) involved shotgun pellets, 24 (52%) bullets, 3 (7%) BB pellets, and 2 (4%) air rifle pellets. All but two of the victims were men with a mean age of 24.1 years (median, 23; range, 5–33). Ten (22%) were 18 years or younger, five (11%) were 16 years or younger, and two of the victims were younger

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Figure 1. Shotgun pellets on abdominal X-ray film.

Figure 2. Pellet emboli visible on X-ray film of the right leg (anteroposterior view).

than 9 years. Five (11%) of the victims died as a result of their wounds. Only two (4%) died as a direct result of missile embolization.

Seventeen cases of shotgun pellet emboli are reported.[2–16] The distance of the shooter was known in nine cases (53%). Of these, six were type III injuries and three were type II injuries with no type I injuries, indicating an association between types II and III shotgun injuries and pellet embolization (Table 1). Sixteen of 17 patients (94%) survived. The single death was caused by multiple emboli entering the portal venous radicals.

Twenty-four cases of bullet emboli are reported.[1,17–39] Of these cases, five (21%) died, but only one (4%) died as a result of the missile embolus. Twelve cases involved an arterial embolus, five (42%) suffering complications as a result of the embolus. Twelve cases involved a venous embolus, with all but one retrieved and complications arising in two.[20,24]

Three cases of BB gun pellet embolus are reported.[40–42] None were fatal. The two cases which involved venous emboli were close range (3 m and 6 m, respectively), with neither case resulting in embolus related complications.

Two cases of air rifle pellet emboli were reported.[43,44] Neither case was fatal. One case involved a venous embolus and the other an arterial embolus, and in both cases, the pellet embolus was removed. No complications were described.

Thirty-four (84%) missile emboli were anterograde (Table 2). Five (11%) were paradoxical, in that they crossed from the right to the left heart. Of the arterial emboli, 23 (96%) were either anterograde or paradoxical. The single retrograde arterial embolus involved a bullet that fell from the right subclavian artery to the right coronary artery causing an inferior myocardial infarction. Sixteen (89%) venous emboli were anterograde. Of the two (11%) retrograde venous emboli, one fell from the right atrium to the inferior vena cava (IVC), the other being found in at autopsy and may have embolised postmortem.

Paradoxical emboli are rare and occur when the missile enters the venous circulation and crosses over to the arterial circulation through an atrial or ventricular septal defect. The incidence of patent foramen ovale in the general population is 27% to 29%.[21]

From the 46 reported cases, 26 (57%) missile emboli lodged in the arterial circulation (Tables 3 and 4). Four (11%) originated in the venous circulation and represented paradoxical emboli. The remaining sites of origin included the heart (12%), pulmonary vein (4%), thoracic aorta or its branches (31%), and abdominal aorta or its branches (15%), with 23% unspecified. Systemic emboli lodged in the carotid system (30%), iliac and femoral system (34%), brachiocephalic and subclavian arteries and their branches (7%), and 4% for each of the aorta, pulmonary artery, basilar artery, renal artery, coronary arteries, and unspecified.

Missile emboli lodged in the venous system in 20 cases (43%) (Tables 5 and 6). Entry sites included the heart (10%), IVC and tributaries (45%), superior vena cava and tributaries (15%), portal vein (5%), and unspecified (20%). Venous

Figure 3. Pellet emboli visible on X-ray film of the right leg (lateral view).

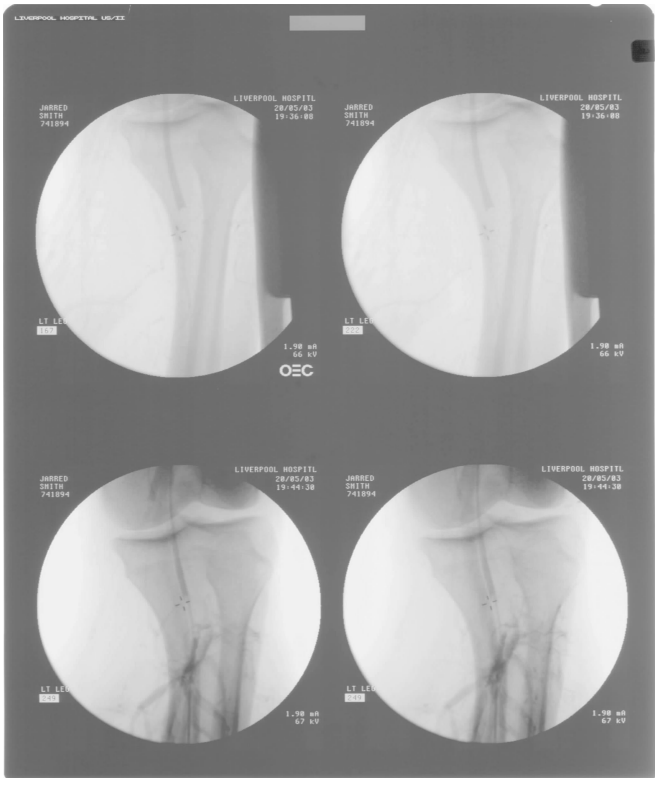

Figure 4. Intraoperative angiogram showing shotgun pellet emboli in the common peroneal and anterior tibial arteries.

emboli lodged in the in the right heart (50%) distributed between the right ventricle (30%) and right atrium (20%). The pulmonary arteries were the destination in 20%, left and right sides with equal frequency. The remainder embolised to the IVC and tributaries (15%), the portal venous system (5%), and unspecified (10%).

Arterial emboli were reported as resulting in symptoms in 69% of the cases (Table 7). They included neurologic ischemia (31%) all but one resulting in permanent deficit, peripheral ischemia (28%), visceral ischemia (7%), sub acute bacterial endocarditis (4%), asymptomatic (7%), and unspecified (23%). In contrast only 25% of cases of venous emboli were reported as resulting in symptoms (ischemia [10%], thrombosis [5%], infection [5%], and palpitations [5%]), with the remaining being asymptomatic (55%) or unspecified (20%).

Treatment was specified in 41 (89%) cases. Fourteen (54%) arterial emboli were retrieved, 10 (38.5%) by open means and four (15%) by catheter assisted embolectomies. Arterial embolectomy was not performed in nine cases (34%) owing to stroke (4 patients), death (1), renal infarction (1), established limb ischemia requiring amputation (1), asymptomatic middle cerebral partial occlusion (1), and asymptomatic pulmonary artery embolus (1). Venous emboli were retrieved in nine cases, five by open and four by catheter assisted procedures. Venous emboli were not retrieved in nine cases owing to death (two cases) or asymptomatic emboli, which were judged to be stable in the right heart (5), IVC (1), and lobar pulmonary artery (1).

TABLE 1. Classification of Shotgun Injuries[2]

Type I	Long range (>12 m) penetration of only the subcutaneous tissue and deep fascia
Type II	Close range (<12 m) penetration below the deep fascia
Type III	Point blank (<5 m) extensive tissue damage

TABLE 2. Anterograde vs. Retrograde Emboli

	N	Percent of Subtotal	Percent of Total
Arterial			
Anterograde	18	75	39
Retrograde	1	4	2
Paradoxical	5	21	11
Subtotal	24		
Venous			
Anterograde	16	89	44
Retrograde	2	11	6
Subtotal	18		
Unknown	4		8
Total	46		100

Pellet embolus after close range gunshot injury is well documented. To our knowledge, this is the first reported case in which such a mechanism of injury has resulted in bilateral lower limb amputations. Rich et al.[45] reviewing wounded soldiers from the Vietnam War found that vascular embolus

TABLE 3. Sources of Emboli to the Arterial Circulation

	n (%)
Carotid	5 (20)
Aorta	
Thoracic	2 (7)
Abdominal	1 (4)
Iliac	2 (7)
Left ventricle	2 (7)
Subclavian	1 (4)
Femoral	1 (4)
Heart (not otherwise specified)	1 (4)
Pulmonary vein	1 (4)
Axillary vein	1 (4), paradoxical
Right atrium	1 (4), paradoxical
Right ventricle	1 (4), paradoxical
IVC	1 (4), paradoxical
Unspecified	6 (23)
Total	26 (100)

TABLE 4. Destination of Arterial Embolism

	n (%)
Carotid and branches	
Left	5 (19)
Right	3 (11)
Femoral and branches	
Left	4 (15)
Right	3 (11)
Subclavian and branches	
Left	0 (0)
Right	2 (8)
Iliac	
Left	1 (4)
Right	1 (4)
Aorta	1 (4)
Pulm art	1 (4)
Basilar	1 (4)
Brachiocephalic	1 (4)
Renal	1 (4)
Coronary	1 (4)
Unspecified	1 (4)
Total	26 (100)

TABLE 5. Sources of Emboli to the Venous Circulation

	n (%)
Femoral	3 (15)
IVC	2 (10)
Iliac	2 (10)
Right atrium	2 (10)
Portal	2 (10)
Pelvic	1 (5)
Axillary	1 (5)
Brachiocephalic	1 (5)
Renal	1 (5)
Jugular	1 (5)
Unknown	4 (20)
Total	20 (100)

TABLE 6. Destination of Venous Embolism

	n (%)
Right ventricle	6 (30)
Right atrium	4 (20)
Pulmonary artery	
Left	2 (10)
Right	2 (10)
Iliac vein	
Left	1 (5)
Right	1 (5)
IVC	1 (5)
Portal system	1 (5)
Unspecified	2 (10)
Total	20 (100)

occurs in 0.3% of vascular trauma cases. Adeboyega et al.[1] reported that since 1834, 160 cases of bullet embolus had been reported of which only four (3%) resulted in limb amputation. Of 46 cases reported since 1995 and reviewed in this article, two patients (4%) underwent amputations: one an above knee amputation and, in our case, bilateral below-knee amputations.

Of the cases reported since 1995, bullet embolus was the most common, followed by shotgun pellet, BB gun, and then air rifle pellet. The differing rate of embolism may reflect the relative frequency with which these weapons are used and reporting bias. Rich et al.[45] suggests that there is a lower incidence of missile embolism in military conflict because of the high powered nature of the weapons involved.

Projectile emboli are usually anterograde as they follow the direction of blood flow in the vast majority of cases. Factors postulated as affecting missile emboli lodgment site include the missile power, caliber and shape, point of entry, gravity (particularly in the low pressure venous system), anatomy of the vessels, force of blood flow,[46] relative size and angle of the arterial branches, and positioning of the victim after being shot.[47]

The neck and upper extremities was the site of embolus lodgment in 42% of cases. The lower limbs were the site of lodgment in 35%, equally distributed between left and right sides, and visceral vessels in 8%. In contrast Shannon et al.[48] report a 17% embolization rate to the neck and upper extremities and 76% rate to lower extremities with the left side affected twice as often as the right. They postulated that the left common iliac artery branches from the aorta at a less acute angle than the right common iliac artery, accounting for this difference.[46] Our review does not support this finding as out of nine missile emboli to the lower limbs, five projectiles embolised to the left side, and four to the right. Similarly, Shen et al.[31] reviewed 14 cases of projectile embolus to the lower limbs after penetrating thoracic aortic injury, where the incidence of left and right sided embolus was equal at seven each.

TABLE 7. Symptoms Associated With Arterial and Venous Emboli

	n (%)
Arterial	
Neurological ischemia	8 (31)
Peripheral ischemia	7 (28)
Visceral ischemia	2 (7)
Infection	1 (4)
Asymptomatic	2 (7)
Unspecified	6 (23)
Subtotal	26 (100)
Venous	
Asymptomatic	11 (55)
Infarction	2 (10)
Thrombosis	1 (5)
Infection	1 (5)
Palpitations	1 (5)
Unspecified	4 (20)
Subtotal	20 (100)
Total	46

Venous emboli most commonly lodge in the right heart or pulmonary vasculature (70%) with equal frequency between right and left sided pulmonary trees. They may result in pulmonary infarction or arrhythmias.

It has been suggested that arterial missile embolus is more common than venous. In this series, arterial embolus occurred in 26 cases (56%) and venous embolus in 20 cases (44%). In Michelassi et al.[49] series of 153 cases, 100 (65%) emboli were arterial and 53 (35%) venous. Both Schmelzer et al.[50] and Rich et al.[45] suggest that arterial missile emboli outnumber venous ones 4:1. However, this is not consistent with the anatomic reality that there is a much larger venous bed and this difference may simply represent reporting bias as venous emboli are less likely to be symptomatic.

However, it is clear that an arterial missile embolus may have more serious outcomes than a venous embolus. In this series, an arterial missile embolus resulted in signs or symptoms of ischemia in 65% of cases. Almost the same percentage of venous missile emboli was asymptomatic. The proportion of complicated arterial to venous emboli was 3:1, whereas the proportion of arterial to venous emboli removed was 1:1. The failure to diagnose and remove a missile embolus in the arterial system may lead to irreversible damage. When this has already occurred, it may not be necessary to remove the missile as was described in nine cases. If the embolus lodges in the cerebral system, then the likelihood of stroke is high. Removal may lead to clinical improvement in the initial neurologic symptoms, but the chance of complete recovery is low.[15]

To identify a missile embolus, a high index of suspicion is required. If the number of entry wounds does not equal the number of exit wounds or the clinical signs and symptoms and radiologic evidence does not correlate with the injury sustained, missile embolus should be considered The sudden loss of a peripheral pulse, unexpected peripheral ischemia, or the sudden onset of new and unexpected neurologic symptoms should raise the suspicion of missile embolus. Methods of investigation can include plain roentgenogram, computerized tomography scan, ultrasound, echocardiography, and angiography. Magnetic resonance imaging should not be used in case the projectile has a ferrous component.

In this series, 54% arterial and 45% of venous emboli were removed. However, missile embolus may cause not merely acute ischemic risk, but may result in complications much later. These may include displacement, erosion, embolization further into the vascular tree, delayed vascular insufficiency, proximal clot formation, septicemia, lead intoxication, or loss of life.[1,50]

Cardiac embolus may cause cardiac irritability, embolise late,[27,50] cause recurrent pericardial effusions, and interfere with valvular mechanisms.[51] Nagy et al.[52] suggested an algorithm for selective management of cardiac missile embolus with intracardiac missiles treated conservatively if they were smooth, firmly lodged, sterile, <5 mm, right sided, and not associated with arrhythmia or valve dysfunction.

Symptomatic peripheral and visceral emboli should be removed by either catheter assisted or open methods.[18] An embolus can be left in place if it has already caused visceral or neurologic infarction[13] and is unlikely to cause any further damage, where the risk of procedure outweighs the benefits of retrieval, and asymptomatic embolus in the portal and pulmonary vasculature. Singer et al.[20] have suggested that all pulmonary arterial missile emboli should be retrieved based on the unpredictability of their movements and the risk of more serious re-embolization. However this re-embolization risk diminishes over time as retained missiles are incorporated into the vessel wall by a pseudointimal covering after 1 week,[53] and in the heart, they are encased in fibrous tissue by 8 weeks.[8]

Finally, a common myth is that missiles are rendered sterile by the mechanism of discharge. All projectiles can carry bacteria. In addition, they can also carry into the wound, skin flora, clothing, and wadding any of which can be can be a source of infection.[54] Bilsker et al.[36] report a case of subacute bacteria endocarditis from *Clostridium difficile* as a result of a bullet entering the left ventricle and subsequently embolising to the right subclavian artery from where it was retrieved.

Although rare, missile embolus should be considered in gunshot victims. It presents a diagnostic and management challenge as the resulting injury is often initially occult and distant from the more obvious injuries caused by the gunshot. Clinical signs and radiologic methods can be used to locate a missile embolus. Once found, the decision to retrieve the embolus is made according to the general condition of the patient and whether it is causing symptoms or may cause them in the future.

Recommendations for Intervention

1. Suspect bullet embolus after a shooting if:
   a. number of entry sites does not equal number of exit sites,
   b. clinical findings do not correlate with injury such as neurologic deficit after a chest wound,

c. changing clinical examination, such as a limb, suddenly becoming pale and cold or focal neurologic signs suddenly becoming apparent, and
d. radiologic and clinical examinations do not agree, such as a missile found on X-ray film in the leg with the only entry wound visible in the abdomen.

2. In types II and III shotgun injuries, patients should be screened for pellet embolus by clinical examination as part of the secondary survey.
3. Surveillance roentgenogram may be used as a quick and cheap investigation and is useful for approximating the position of a projectile that has strayed from its point of entry and embolized.
4. If a projectile embolus is found, it should be removed urgently if it is causing symptoms or it is thought that it may cause symptoms or complications in the future unless irreversible damage to the supplied organ has occurred.
5. If the embolus is not removed, prophylactic antibiotics should be considered for all invasive medical procedures.
6. To aid in the identification of possible sites of lodgment, the following principles should be considered
   a. Arterial missile embolus:
      - The thoracic aorta and its branches are the most common site of origin.
      - The lower limbs and carotid arteries are the most common sites of destination.
      - 65% to 70% are symptomatic.
   b. Venous missile embolus:
      - The IVC and its tributaries are the most common site of origin.
      - The right heart is the most common site of destination with almost one-third finally lodging in the lungs.
      - 25% to 33% are symptomatic.
   c. Most missile emboli are anterograde.

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