

## CASE REPORT

# Pulmonary Artery Bullet Emboli: To Retrieve or Not? A Contemporary Reassessment

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### ABSTRACT

**Aim:** We present two patients with bullet emboli to the pulmonary artery and discuss their management based on a review of the literature.

**Background:** Bullet emboli to the pulmonary arteries from abdominal gunshot wounds are rare. It is unclear whether these bullets should be removed in stable, asymptomatic patients.

**Case description:** We discuss the management of two cases of bullet emboli to the pulmonary arteries and the associated morbidity and mortality, based on a thorough review of the relevant literature.

**Conclusion:** We recommend elective removal of the asymptomatic bullet to the pulmonary artery once patients have been appropriately resuscitated or on a close follow-up of the compliant patient.

**Clinical significance:** The complex management of these patients necessitates an individualized management with a collaborative approach between cardiothoracic and trauma surgeons.

**Keywords:** Bullet, Chest, Embolus, Penetrating trauma, Pulmonary artery.

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### RESUMO

**Objetivo:** Apresentamos dois pacientes com êmbolo de projétil de arma de fogo (bala) na artéria pulmonar e discutimos seu manejo com base em uma revisão da literatura.

**Antecedentes:** Os êmbolos de bala nas artérias pulmonares decorrentes de ferimentos por arma de fogo abdominais são raros. Não está claro se essas balas devem ser removidas em pacientes estáveis e assintomáticos.

**Descrição do caso:** Discutimos o tratamento de dois casos de êmbolos de projétil de arma de fogo (bala) nas artérias pulmonares e a morbimortalidade associada, com base em uma revisão minuciosa da literatura relevante.

**Conclusão:** Recomendamos a remoção eletiva do projétil de arma de fogo assintomático na artéria pulmonar, uma vez que os pacientes tenham sido adequadamente ressuscitados ou após acompanhamento de perto destes pacientes.

**Significado clínico:** O manejo complexo desses pacientes requer planejamento e condução individualizados, com uma abordagem colaborativa entre os cirurgiões de trauma e os cardiotorácicos.

**Palavras chave:** Artéria Pulmonar, Bala, Embolia, Projétil de Arma de Fogo, Tórax, Trauma penetrante.

### BACKGROUND

Bullet emboli to the pulmonary arteries resulting from distant gunshot wounds are exceedingly rare. It remains unclear if asymptomatic patients should preemptively undergo bullet removal. We present two patients with bullet emboli to the pulmonary artery and review the reported cases in the literature to optimize their management.

### CASE 1

A 40-year-old male was shot from close range to his extremities and abdomen. He was alert and oriented with a blood pressure of 80/40 mm Hg with a heart rate of 130's in the field. At the trauma center, he had a blood pressure of 140/80 mm Hg and a pulse rate of 123 beats per minute. He was noted to have a gunshot wound to the epigastrium and a through-and-through injury to both the left forearm and the thigh. Lateral and upright chest X-rays demonstrated a foreign body, consistent with a bullet, posterior to the heart. At laparotomy, he was noted to have >2 L hemoperitoneum with injuries to the transverse colon, jejunum, third portion of the duodenum, and a non-expanding zone-I retroperitoneal hematoma. Intraoperatively, he was hypothermic

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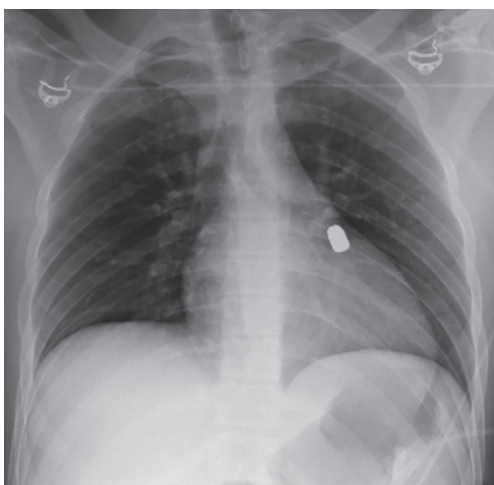
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to 34° and acidotic to a pH of 7.22. Upon medial visceral rotation, a through-and-through injury to the inferior vena cava below the level of the renal veins was identified and repaired primarily. A damage control laparotomy was performed with the rapid repair of the colon, resection of the jejunum, and repair of the third portion of the duodenum. The abdomen was packed, leaving the bowel in discontinuity. The abdomen was left open. He was returned to the

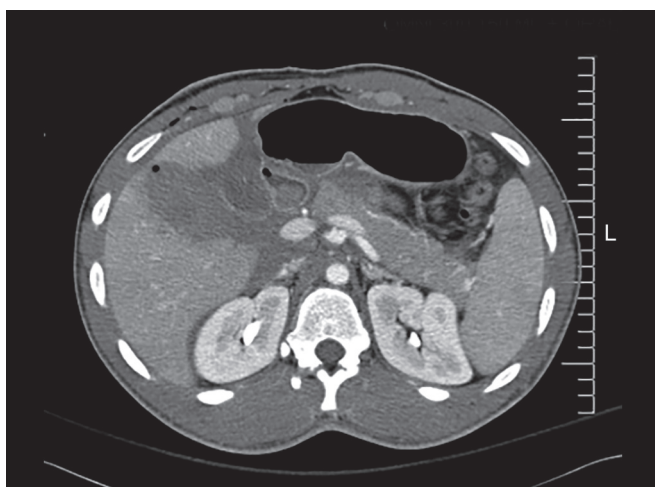


**Fig. 1:** AP and lateral chest X-ray showing bullet posterior to heart

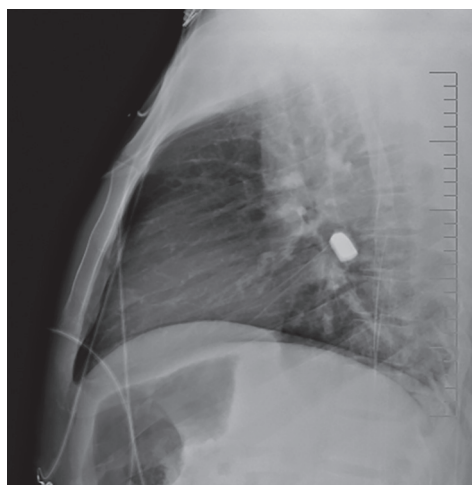
operating room after resuscitation. The segments of the jejunum were anastomosed and the colon was re-anastomosed as a colocolostomy. The patient did well postoperatively until day 22, when he became febrile with an elevated white blood cell count of 22 K. He had scattered rales and rhonchi at the left base. Computerized tomography (CT) scan of the chest and the abdomen were obtained and showed evidence of a left lower lobe pneumonitis, a foreign body (bullet) in the left lower lobe and an insignificant abdominal CT. Even though a bronchoscopy and bronchoalveolar lavage were negative for organisms, he was started on antibiotics. He became increasingly septic, however, and subsequently developed septic shock. A thoracotomy and lower lobectomy were emergently scheduled, but he expired from sepsis before he could be taken to the operating room. An autopsy confirmed a necrotizing pneumonia of the left lower lobe adjacent to the retained bullet.

## CASE 2

A 21-year-old male sustained a gunshot wound to the right upper quadrant. Prior to abdominal exploration, anterior-posterior and lateral chest X-rays demonstrated a single bullet posterior to the heart with no evidence of pneumothorax or hemothorax (Fig. 1). A focused assessment with sonography in trauma (FAST) exam was negative for the pericardial fluid. Abdomen/pelvis CT showed a complex liver



**Fig. 3:** Chest CT scan image demonstrating bullet lodged in pulmonary artery



**Fig. 2:** Abdomen/pelvis CT scan image demonstrating liver injury and fluid surrounding duodenum

injury with fluid surrounding the duodenum (Fig. 2). Chest CT scan demonstrated a single bullet lodged in the left pulmonary artery (Fig. 3). At the time of laparotomy, he was noted to have a complex liver laceration, duodenal injury, and laceration of the anterior wall of the inferior vena cava at the level of the right renal vein. These injuries were managed with primary repair. Subxiphoid pericardial window performed was negative for blood. A missile embolus was diagnosed but was left in situ. He improved postoperatively and was discharged home without bullet removal. An echocardiogram (ECHO) was planned for 6 months later to evaluate his right heart function. Seven weeks later, the patient presented with chest pain and shortness of breath with oxygen saturations of 97% on 100% oxygen non-rebreather. A chest CT scan showed evidence of a large left pneumothorax with a concern for broncho-pleural fistula and empyema. Following chest tube placement, he was taken emergently to the operating room for exploration. There was 300 cc of purulent material in the chest and over 50% of the left lower lung was necrotic. A left lobectomy was performed through a thoracotomy incision. Pathology was consistent with subpleural hematoma and infarction with adjacent acute pneumonia and acute fibrinous pleuritis. Microbiology was positive for *Streptococcus milleri* and mixed anaerobic bacteria. He completed a 4-week course of Zosyn which was converted to Augmentin for an additional 2 weeks of coverage. He did well on follow-up.

## DISCUSSION

The optimal management in arterial missile emboli is agreed upon uniformly. It is, however, not as clear on the venous side, because of the need for a major procedure of thoracotomy and the “presumed” absence of clear-cut threat for complications. “Presumed” because a careful review of the reported experience raises some questions whether non-interventional observation is always a good option in pulmonary missile emboli. Further, recent innovations in minimally invasive surgical techniques and interventional radiological and hybrid procedures provide a less severe alternative option to thoracotomy.

To reevaluate the management in this era of technologic advances, we have rereviewed the existing literature, adding two cases of pulmonary artery bullet emboli. Literature search revealed three significant reports of the phenomenon: Shannon et al. (126 cases, 1929–1987)<sup>1</sup> and Miller et al. (45 cases, 1987–2011).<sup>2</sup> We found an additional 17 cases to date including the two reported here. These are summarized in Tables 1 and 2.<sup>3–55</sup>

**Table 1:** Venous missile embolism—literature summary 1900–1929; 1930–1987, Reproduced with permission, Shannon et al.<sup>1</sup>

	Origin		Final destination	Date of report	
	Below diaphragm	Above diaphragm		1900–1929	1930–1987
23		4	Right heart	13	48
			Missile removed	1 (8%)	32 (67%)
			Embolus morbidity	0	3 (6%)
			Embolus mortality	5 (62%)	1 (4%)
16		13	Pulmonary artery	7	38
			Missile removed	0	21 (55%)
			Embolus morbidity	0	7 (18%)
			Embolus mortality	5 (71%)	3 (8%)
7		8	Peripheral/central vein	3	12
			Missile removed	2 (66%)	7 (58%)
			Embolus morbidity	0	2 (17%)
			Embolus mortality	0	0
5		0	Paradoxical systemic artery	1	4
			Missile removed	0	4 (100%)
			Embolus morbidity	0	4 (50%)
			Embolus mortality	1 (100%)	0
51		25	Total	24	102
			Missile removed	4 (17%)	64 (64%)
			Embolus morbidity	0	14 (14%)
			Embolus mortality	11 (46%)	4 (4%)

**Table 2:** Reported cases of venous embolism (1987–2016)

S. no.	Author (year)	Site of primary injury	Visceral injuries	Treatment
1	Rehm et al. (1988)	Chest	Rt hepatic vein	Endovascular
2	Patel et al. (1989)	Abdomen	PA 1	Observation
3	Patel et al. (1989)	Abdomen	PA 2	Observation
4	Patel et al. (1989)	Abdomen	Right atrium	Open removal
5	Schmelzer et al. (1989)	Chest	L SC vein popliteal vein	Observed
6	Vázquez-Valdés et al. (1989)	Chest	PA PL	Thoracotomy
7	Michelassi et al. (1990)	Abdomen	Right atrium	Sternotomy/cardiopulmonary (CP) bypass
8	John and Edmondson (1991)	Abdomen	Pulmonary artery (PA)	Unknown
9	Van Arsdell et al. (1991)	Head	Right ventricle	Open
10	Colquhoun et al. (1991)	Neck	Right ventricle	Sternotomy/CP bypass
11	Colquhoun et al. (1991)	Inguinal	Rt atrium	Sternotomy/CP bypass
12	Kortbeek et al. (1992)	Abdomen	PA	Observation
13	Martí et al. (1991)	Chest	Superior vena cava (SVC) right ventricle	Unknown
14	Nazir et al. (1992)	Chest	Right ventricle	Open/failed endovascular
15	Nagy et al. (1994)	Lower extremity	Iliac right ventricle	Observation
16	O'Neill et al. (1996)	Abdomen	RV Inferior vena cava (IVC) RA	Transjugular
17	Panichabhongse et al. (1996)	Abdomen	Right (Rt) PA	Observation
18	Schurr et al. <sup>45</sup> (1996)	L external iliac vein PFO open, Common iliac artery L	Ex Lap, open removal w/ arteriotomy	
19	Headrick et al. (1997)	Abdomen	IVC right ventricle	Sternotomy/CP bypass
20	Lodder (1997)	Lower extremity	PA	Observation
21	Schöpf et al. (1998)	Head	PA	Unknown
22	Kaushik and Mandal (1999)	Lower extremity	Iliac vein RA	Endovascular
23	Pollak et al. (1999)	Inguinal	Right atrium	Observation
24	Obermeyer et al. (2000)	Buttock	Right ventricle	Observation

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S. no.	Author (year)	Site of primary injury	Visceral injuries	Treatment
25	Luison and Inculet (2001)	Chest	R Brachiocephalic Vein PA	Observation
26	Best (2001)	Buttock	Right heart	Transfemoral extraction endovascular (EV)
27	Wales et al. (2001)	Chest	Right ventricle	Sternotomy w/CP bypass
28	Kalimi et al. (2002)	Buttock	Right ventricle	Failed retrieval, observation And sternotomy/CP bypass
29	Lucena and Romero (2002)	Chest	External iliac vein	Autopsy
30	Berkan and Gu nay (2002)	Inguinal	Right ventricle	Observation
31	Corbett et al. (2003)	Inguinal/Flank	IVC PFO common femoral artery	Open
32	Bertoldo et al. (2004)	Chest	SVC iliac IVC	Thoracotomy
33	Bett and Walters (2004)	Neck	Right ventricle	Observation/pacemaker
34	Demirkilic et al. (2004)	Lower extremity	PA	Sternotomy/CP bypass
35	Hughes and Vender (2006)	Head	PA	Observation
36	Agarwal et al. (2007)	Neck	PA	Thoracotomy
37	Bining et al. (2007)	Flank/lower extremity	Right ventricle	Sternotomy
38	Breeding et al. (2007)	Neck	Right atrium	Sternotomy/endovascular
39	Chen et al. (2007)	Flank	PA	Endovascular
40	Dulić et al. (2007)	Lower extremity	PA	Observation
41	Ettinger et al. (2007)	Chest	Right heart	Sternotomy/CP bypass
42	Bors et al. (2008)	Chest	L BC vein right ventricle	Open removal/CP bypass
43	Engelgardt et al. (2008)	Head	SVC IVC femoral vein	Autopsy
44	Raikar et al. (2009)	Buttock	Hepatic vein	Endovascular
45	Jo et al. (2010)	Head	PA	Thoracotomy, embolectomy
46	Miller et al. (2011)	Left chest	Suprahepatic cava	Snare, trans Fem venous (Vn)
47	Miller et al. (2011)	Rt chest	Rt ventricle	Snare, trans Fem
48	Miller et al. (2011)	Transpelvic	IVC, colon, Rt atrial appendage	Transluminal snare right internal jugular (Rt IJ)
49	Miller et al. (2011)	Abdomen	Enteric, IVC, Rt ventricle	Transluminal endosnare thr cavotomy
50	Nolan et al. (2012)	Abdomen	IVC, retrohep cava to iliac	Snared, removed by femoral Vn
51	Gustavo (2013)	Right buttock	Rt iliac vein to Rt PA	Endo snaring unsuccessful. Observed
52	Wilkins (2014)	Chest	L Pulmonary artery	post lat thoracotomy
53	Duke et al. (2015)	BB to right globe	Trans (Tr) sinus right heart, PA	Left alone
54	Lu et al. (2015)	Abdomen, iliac,	Rt ventricle	Ensnare, later sternotomy
55	McTyre et al. (2015)	Abdomen	PA	None, OK
56	Eicevarra (2015)	Thighs	PA	Failed snaring. thoracotomy,
57	Doud et al. (2015)	Abdomen	Bowel, ureter rt ventric septum	Sternotomy
58	Pavlekić (2016)	Thigh, neck	IJ, ext iliac	Autopsy
59	Imbert (2016)	Chest	Right ventricle	Observation. Embolized twice
60	Wilkins (2016)	Chest	Right middle lobe of the lung, the right hemidiaphragm, segments 4A and 1 of the liver, and the intrahepatic IVC	Thoracotomy
61	Goldberg (2016)	Abdomen	Colon, IVC	Autopsy
62	Goldberg (2016)	Abdomen	Duodenum, colon, IVC	Thoracotomy

After: Appendix<sup>2</sup>

Bullet embolism is a rare, potentially life-threatening complication of penetrating missile trauma. It occurs when a small-caliber bullet enters the blood stream<sup>1,2</sup> with enough velocity to penetrate one wall of a vessel. It loses momentum once inside the lumen, as might happen with BBs, 0.22 caliber bullets, airgun pellets, or shotguns ammunition. The free-floating foreign body may then be carried by the bloodstream or if free within a body cavity, by

gravity or a change in body position.<sup>1-5</sup> Migrating venous bullets lodge in the right ventricle more often than the pulmonary arterial tree since they tend to be trapped beneath the tricuspid valve or the chordae tendinae. Arterial missile emboli are carried downstream in the arterial tree after the bullet is lodged in the left side of the heart or the major arterial branches. Paradoxical emboli cross over from the venous system to the arterial system, either through a large



A–V fistula or, as is more usual, through a patent foramen ovale.<sup>1,2,17</sup> Rarely, a double play is to blame: Corbett<sup>30</sup> described a case where a bullet to the flank and groin embolized to the common femoral artery, via retrohepatic cava, right heart, patent foramen ovale, and then the arterial circulation.

The first reported venous embolus was by Davis in 1834 as a case of a wooden fragment embolizing from the venous circulation to the right ventricle in a 10-year-old boy.<sup>52</sup> Bullet embolism should be suspected by an odd number of missile wounds or a bullet lies outside the established trajectory, or suggested by changing position of a missile on radiographs. In the majority of cases, the initial wounding site is the chest or the abdomen. Rarely the head and the neck or extremity penetration was the primary site of entry. The emboli may be discovered both at the time of presentation and as late as 59 years after the initial injury.<sup>50</sup>

There is no consensus on whether aggressive retrieval is necessary for asymptomatic patients.<sup>1,2,7,11,14,18,45–51</sup> Reasons for removal of bullet emboli to the pulmonary artery include complications of bullet erosion, local hemorrhage, and pulmonary infarction with the risk of infection.<sup>1–5</sup> Studies supporting the removal of venous bullet emboli stem from data showing a 13% complication rate from retained right heart missiles often months to years following the initial injury.<sup>1,2</sup> Similarly, in a review of 102 cases reported since 1930, Shannon et al.<sup>1</sup> demonstrated a retrieval rate of 64% and an embolus-related mortality of 4%, Table 1. These authors advocated bullet extraction given the high morbidity and considerable mortality rate. In the reported cases since 1987, more than 50% of emboli underwent intervention.<sup>2</sup> The majority of them were extracted through open operation (24/61), endovascular (11/45), or hybrid open/endovascular (2/61) approaches. Four cases were at autopsy. In three cases, the management was unclear. Five open procedures were performed following failed endovascular retrieval (Table 2).

Eighteen of the 61 cases were managed by careful observation, with most of these restings within the pulmonary artery in asymptomatic patients. In a couple of patients, initial attempts at endovascular attempts failed and the patients were observed without further treatment. Conservative management was advocated by Kortbeek et al.,<sup>11</sup> who in 1992 reviewed 32 cases of pulmonary artery bullet emboli that were observed without complication. Observation is apparently appropriate when bullets lodged in the pulmonary tree do not cause a pulmonary infarction, pulmonary abscess, or erosion in the bronchus or when the emboli were detected late after the primary event.<sup>1</sup>

More than 50% (10/16) of the interventions for bullet emboli reported since 2007 underwent either an endovascular or a hybrid retrieval. The series of Miller et al.<sup>2</sup> reported in 2011 documented a 100% endovascular retrieval in the reported four cases. A recent report emphasized the use of endovascular retrieval of bullet embolism.<sup>45</sup> These techniques have reduced the morbidity and the mortality of intracardiac bullet retrieval, and have favored prophylactic retrieval of bullet emboli to prevent complications. Endovascular bullet retrieval still requires surgical bullet extraction through arteriotomy and venotomy.<sup>1,2</sup> Whether the advent of newer techniques or the decreased morbidity from avoiding a thoracotomy should influence the decision to proceed with bullet retrieval in the hemodynamically stable patient remains unknown. The question becomes even more pertinent for embolized bullets that became contaminated by trans-enteric migration.

Traditional surgical dogma would suggest that bullet penetration of the gastrointestinal tract and subsequent embolization would present the chance for infection around the embolization site,

perhaps augmented by adjacent tissue necrosis. This may explain the not-too-infrequent finding of associated pulmonary infarction. It is conceivable that bullets undergoing trans-colonic penetration with higher bacterial counts may lead to higher associated infection rates around these embolized bullets than those without associated enteric penetration. Shannon et al.<sup>1</sup> strongly support this concept as a reason to extract such embolized bullets. Similarly, whether the source of infection arose from a bullet contaminated with enteric contents bathed in the blood or from the infarcted lung tissue remains unknown. Both patients presented in this series, however, developed bullet-associated lung infection and sepsis after their migration through the duodenum and the colon. It is also sobering to realize that this resulted in a septic death of one of our two cases.

The cases reported in the literature also provide fascinating operative facts. In four of nine patients who underwent thoracotomy for retrieval, the missile was dislodged during manipulation and a second thoracotomy was required in three of them.<sup>56</sup> In one recent report of a bullet embolus to the inferior branch of the pulmonary artery,<sup>52</sup> interventional radiology was unsuccessful in attempts at endovascular bullet retrieval necessitating operative retrieval through a left posterolateral thoracotomy. During dissection and mobilization of the left pulmonary artery, the bullet became dislodged and was no longer palpable. Intraoperative chest radiograph revealed that the bullet had traveled into the right PA! The left thoracotomy incision was closed with a towel clip closure and the patient placed the right side up in the decubitus position. Vigorous percussion of the right chest relocated the missile to the left side as confirmed by a chest X-ray. The bullet was extracted through a pulmonary arteriotomy. The authors commented on the intraoperative use of an inflated Swan-Ganz catheter to prevent bullet migration during patient positioning and operative manipulation.<sup>52</sup>

## CONCLUSION

Based on a review of the reported experience on pulmonary missile emboli, we recommend elective removal even in the asymptomatic patient when the bullets are potentially contaminated by trans-colonic migration.

## CLINICAL SIGNIFICANCE

The complex management of these patients necessitates a collaborative approach between cardiothoracic and trauma surgeons to decrease morbidity and mortality among this very rare group of patients.

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