

Considerations about ballistic embolism: experience at the João XXIII Hospital

Considerações sobre êmbolo balístico: experiência do Hospital João XXIII

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ABSTRACT

Ballistic embolism is an unusual presentation of penetrating vascular trauma. Its diagnosis is challenging, and its treatment is controversial. The complications are potentially lethal. The development of new technologies allowed increased diagnostic accuracy and minimally invasive therapy. This review presents the experience at the João XXIII Hospital (Trauma Reference Center) in the assistance to four cases involving this type of trauma. A great clinical diversity is observed; the currently considered the most appropriate approach is presented.

Key words: Wounds and Injuries; Wounds, Gunshot; Forensic Ballistics; Wounds, Penetrating; Embolism.

RESUMO

A embolia balística é apresentação incomum do trauma vascular penetrante. Seu diagnóstico é desafiador e o tratamento controverso. As complicações são, potencialmente, letais. O desenvolvimento de novas tecnologias permitiu mais precisão diagnóstica e terapêutica minimamente invasiva. Esta revisão apresenta experiência do Hospital João XXIII (Centro de Referência em Trauma) na condução de quatro casos envolvendo esse tipo de trauma. Observa-se grande diversidade clínica e apresenta-se abordagem considerada atualmente a mais adequada.

Palavras-chave: Ferimentos e Lesões; Ferimentos por Arma de Fogo; Balística Forense; Ferimentos Penetrantes; Embolia.

INTRODUCTION

The definition of ballistic embolus is found in medical dictionaries as follows:

- **embolus:** foreign particle, formed by an air bubble, cellular tissue, fat, blood clot, etc. that enters the bloodstream. Clot or foreign body (bullet) causing embolism;
- **ballistic:** concerning ballistics;
- **ballistics:** the science of motion and behavior of thrown bodies in a space especially of projectiles propelled by explosives.

The embolization of ballistic projectiles is unusual in penetrating vascular trauma.^{1,2} Foreign bodies enter the cardiovascular system and embolize in various directions causing diagnostic confusion.^{2,3} The handling of these cases is challeng-

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ing and controversial.^{1,4} The surgical treatment and non-operative conduct find some indications.^{1,5} The technological advancement and development of endovascular procedures propose new perspectives on treatment for these cases.^{1,3}

The knowledge on this theme developed throughout the years is based on few published reports. For the past eight years, four cases were treated in the João XXIII Hospital, which exposes its experience in the diagnosis and treatment of this unusual trauma.

CASE REPORT

Case 1: In 2006, NSB, male, 39 years old, suffered aggression by a firearm, with one hole in the right arm and another in ipsilateral thoracoabdominal. Presented hemodynamic stability at hospital admission, with mild dyspnea and no abdominal pain. Patient was submitted to right hemi thoracic drainage in water seal with exteriorization of little air and 100 mL of blood secretion. The anteroposterior thorax radiography (AP) showed expanded lung and metal projectile in the right paramedian region, near the ninth thoracic vertebra. The computed tomography (CT) of chest and abdomen revealed a metallic projectile located in the branch of the left pulmonary artery, hepatic lesion grade III with little free liquid in the abdomen, and small hemopneumothorax on the right. He evolved without complications. The chest drain was removed in 48 hours. He remained asymptomatic and was discharged on the seventh day of hospitalization (Figures 1 and 2) (all figures were taken from the authors' personal file).



Figure 1 - Thorax CT (axial view): metallic projectile in the branch of the left pulmonary artery.



Figure 2 - Thorax CT (3D reconstruction): metallic projectile in the branch of the left pulmonary artery.

Case 2: In 2006, NMJ, male, 18 years of age, suffered aggression by a firearm, with one hole in the right posterior axillary line. Presented tachypnea with saturimetry of 84% at admission, soft tissue emphysema in the right thorax wall and no abdominal pain. Patient was submitted to right hemi thoracic drainage in water seal with the removal of 1,150 mL of hemorrhagic. Volemic resuscitation was followed by clinical stability. The anteroposterior chest radiograph revealed a metal projectile in the heart area. The chest CT showed a projectile in the heart area. The echocardiogram showed free fluid in the pericardial sac and a projectile in the heart area. Patient was submitted to sternotomy, which showed a lesion in the right atrium that was submitted to raffia. It was not possible to retrieve the projectile during surgery. In the postoperative period, the patient was submitted to abdomen TC, which revealed the projectile location in the inferior vena cava. The endovascular treatment was performed with the right femoral vein puncture and projectile removal with a basket type catheter (basket). He evolved without complications and was discharged on 12th day of hospitalization (Figures 3 to 8).



Figure 3 - AP thorax x-ray: metal projectile in the heart area (pre-operation).

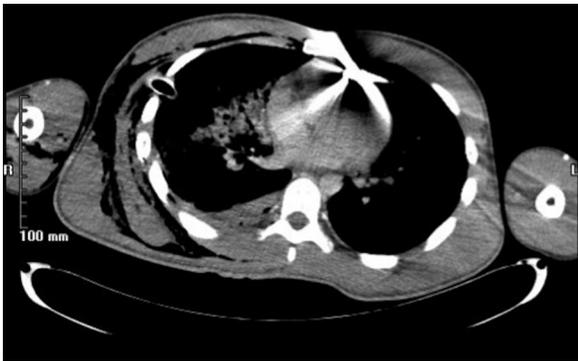


Figure 4 - Thorax CT (axial view): metallic projectile in the cardiac area (pre-operation).



Figure 5 - AP abdomen X-ray: metallic projectile in the abdominal region (post-sternotomy).

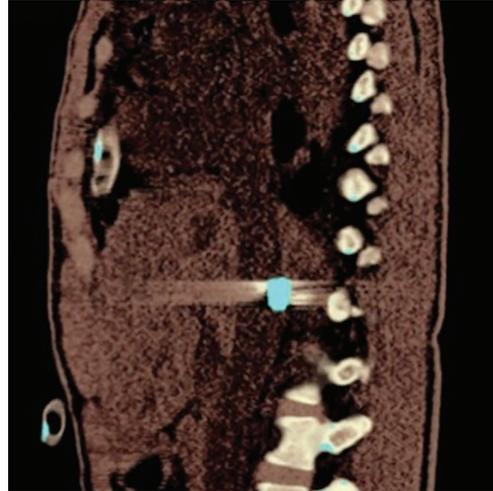


Figure 6 - Abdomen CT (sagittal view): metallic projectile in the inferior vena cava (post-sternotomy).



Figure 7 - Hemodynamics: metallic projectile in the left renal vein and the end of the catheter close to it.

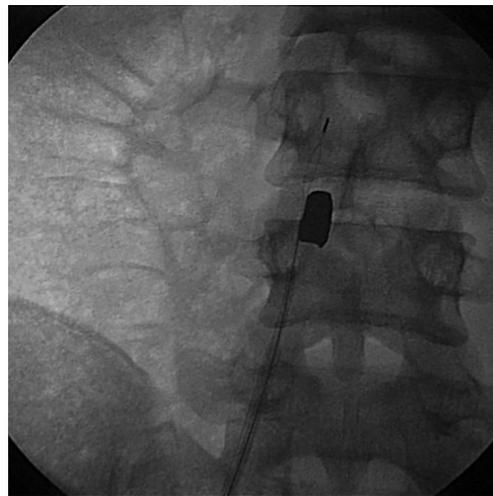


Figure 8 - Hemodynamics: metallic projectile in inferior vena cava being pulled by the type basket catheter (basket).

Case 3: In 2011, IFRM, male, 18 years old, was admitted to the João XXIII Hospital with hypotension due to an aggression by a firearm. One hole was detected in the epigastrium and another in the right jaw angle. He was submitted to thoracotomy resuscitation and laparotomy. Hemoperitoneum was moderate, and retroperitoneal hematoma was voluminous without active bleeding. Aortic clamping was performed in the chest and above the iliac bifurcation, as well as periaortic hematoma exploration. One single lesion was identified in the left anterolateral abdominal aortic wall, below the celiac artery, and above the renal arteries. Raffia aortic lesion was performed with prolene 5.0 and four patties were positioned in the retroperitoneal space and one in the hepatic lesion. An alternative closure of the abdomen with Bogotá bag was performed. Patient evolved with evidence of ischemia in the right lower limb. The radiography of the right thigh registered one metal projectile in its medial surface. Surgical local exploration was conducted, which detected the projectile in the right femoral artery. Proximal and distal vascular control was achieved followed by arteriotomy with projectile removal and arterial raffia. The evolution was uneventful after definitive treatment (Figures 9 and 10).



Figure 9 - AP X-ray of the right thigh: metallic projectile in the medial thigh region.

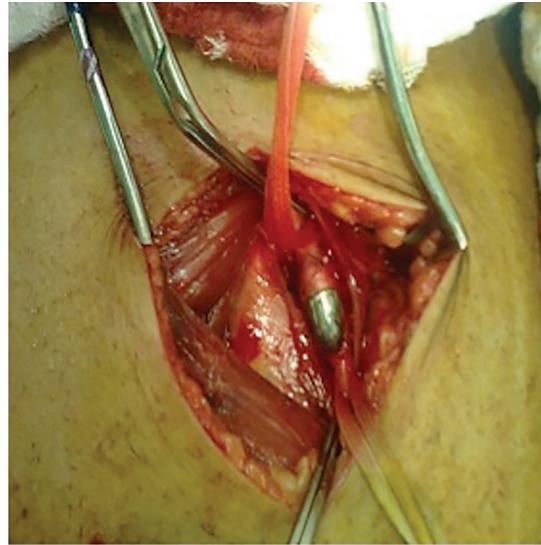


Figure 10 - Open surgery: metallic projectile being removed from the right femoral artery.

Case 4: In 2012, LAS, male, 17 years old, was admitted to the João XXIII Hospital hemodynamically stable, with light tachypnea and abdominal pain after aggression by a firearm. One hole in the right lumbar region was identified, two in the right thigh, and two in the right leg. The abdomen and pelvis computed tomography showed hepatic lesion grade III, and one metallic projectile was located in the inferior vena cava (near the confluence of the hepatic veins), retroperitoneal hematoma, hemopneumothorax to the right, and pulmonary contusion. The abdominal ultrasound showed one metal projectile in the inferior vena cava, mobile at respiratory movements. Patient was submitted to thoracic drainage in water seal with little air output and 150 mL of blood secretion. We opted for the non-operative treatment due to the patient's clinical stability. On the second day of hospitalization, the projectile was located in the lower abdominal region to the left. Endovascular treatment was performed, which detected the projectile in the left common iliac vein; projectile was removed with the help of a type loop catheter (snare). Patient evolved without complications and was discharged on the 10th day of hospitalization (Figures 11 and 12).



Figure 11 - Abdomen CT (axial view): metallic projectile in inferior vena cava.



Figure 12 - AP abdomen X-ray: metallic projectile in left hemipelvis.

DISCUSSION

The embolism caused by firearm projectiles is unusual, with the description of a little more than 150 cases,^{1,4} most of them in isolation.^{2,5,7} The first case report of embolism caused by a foreign body in the cardiovascular system dates from 1834 and is attributed to Thomas Davis,^{1,2} a 10-year-old boy victim of embolism by a piece of wood in the right side of the heart.^{1,6}

The incidence of embolism caused by firearm projectiles has not changed much in the last 70 years. In

the Second World War and Viet Nam War, the reported incidence was of 0.3% among American soldiers.^{1,4} In the Lebanon war, more recently, the reported incidence is 0.4%.^{1,4} It is more common among young people, from 20 to 30 years of age (79.4% of cases).^{1,4} This is a further evidence of the great exposure of the young population to penetrating trauma.⁴ Men (87.8% of the cases) are more affected than women (12.2%).¹ There are more cases related to civil social violence (85% of cases) and fewer cases related to wars (15%).^{1,4}

The mechanism of trauma associated with embolism by firearm projectiles involves rupture, crushing, laceration, abrasion, and burning of tissues.² Projectiles lose motion energy and may suffer alterations during their trajectory in the body.² When they hit and harm the wall of a vessel, they have little energy to be absorbed, allowing their entry into the cardiovascular system. From that moment, they can reach different parts of the body as an embolus.⁴ Most arterial and venous ballistic emboli migrate according to the blood flow direction.^{1,4,8} The projectile dislocation can happen through the arterial or venous system.^{1,4,8} Projectiles entering the venous system commonly migrate to the right side of the heart and often continue to the pulmonary arterial tree.^{1,4,8} Those that enter the left side of the heart and aorta embolize the top part (neck) or, more commonly, the lower extremities.^{1,4}

The left lower limb is twice more affected than the right.¹ The bifurcation of the iliac vessels occurs with an angle of 30° to the left and 45° to the right.¹ The projectile's intravascular penetration may result from a direct injury to the heart or other vascular sites.^{1,2} After the penetration, the projectile can migrate through the intravascular route. Migration generally occurs immediately after the trauma.^{1,2} However, migration has been described 14 years after of the event.²

Some reports described an embolus displacement during surgery.^{1,2} Most cases of ballistic embolism involves the arterial system (70% of cases).^{1,2,7} Venous embolism is less representative (30% of cases). Cases of arteriovenous and venous arterial embolism are even less common.^{1,3,9} The arterial wall is more firm and elastic allowing better accommodation of the projectile inside the injured vessel. There are reports of paradoxical embolism (1% of cases) in which the embolus moves between the two systems through arteriovenous fistulas.^{2,3,9} Fistulas can be traumatic (caused by the projectile itself) or congenital (foramen ovale - one hole in the septum between the two left and right cardiac atriums).^{2,3,9} The retrograde

embolism (14% of cases) occurs when the projectile migrates in the opposite direction of blood flow.^{2,3} This happens by the influence of some factors such as the weight of the foreign body, patient's position, and gravity action.^{2,3,7}

The migration is also influenced by other variables such as projectile's speed, size and shape of embolus, muscle and respiratory movements, vascular anatomy, and flow speed of the vessel involved.^{2,3,7} The path of the embolus seems to relate directly to the patient's position shortly after the trauma.^{2,7} The impaction level depends on the embolus' gauge and diameter of the vase.^{4,7} It mainly occurs in vascular bifurcations because these are places where the vessels' caliber sharply decrease.^{4,7} The most commonly occluded vessel in arterial embolism is the femoral artery (30 to 50% of cases).^{2,4}

There are several materials related to post-traumatic or iatrogenic embolism, especially needles, pins, catheter tips, pieces of wood, thorns, metal fragments, and firearm projectiles.¹⁻³

The ballistics embolism involves the direct lesion caused by the embolus (blockage, erosion) and the organism's reactions to the foreign body inserted into the cardiovascular system. They can be little symptomatic (30% of cases) or asymptomatic (70%).^{1,2,10} The arterial embolism is more symptomatic (70% of cases) than the venous (35%).^{1,2} The clinical manifestations, when present, are influenced by factors such as the embolus' location and thrombotic, ischemic, or hemorrhagic complications.¹⁻³ The symptoms associated with complications may be pain, dyspnea, asthenia, thrombosis, ischemia, chest pain, hemoptysis, thrombophlebitis, arrhythmias, valve dysfunction, endocarditis, sepsis, vascular erosion or occlusion, pseudoaneurysms, and bleeding.¹⁻³ In addition, neuroses, psychoses, pericardial effusion, pleural effusion, gangrene, claudication, and peripheral vascular insufficiency can occur.²

The identification of infection and ischemia in organs and tissues distant from the entry wound may result from vascular embolism; some patients may require amputations or die.² There are reports of penetration in the cardiovascular system after the ingestion of a foreign body.² Lesions in the gastrointestinal tract makes the projectile contaminated.² In such cases, the risk of infection is high and can determine the need for embolus removal.² Embolism of projectiles in the digestive (swallowing) and bronchial (aspiration) tracts are also possible including their associated complications^{2-4,10} (Tables 1 and 2).

Table 1 - Symptoms associated with arterial and venous ballistic embolisms

	N	%
Arterial Embolism	100	
Peripheral Ischemia	30	66.7
Neurological deficit	6	13.3
Asymptomatic	9	20.0
Unspecified	55	-
Venous Embolism	53	
Asymptomatic	15	65.2
Chest pain, dyspnea, hemoptysis	4	17.4
Extrasystoles	1	4.35
Arterial compression	1	4.35
Thrombophlebitis	1	4.35
Infection	1	4.35
Unspecified	30	-

Michelassi F. Surgery. March, 1990.

Table 2 - Ballistic embolus source to the systemic circulation

Location	N	%
Thoracic aorta	22	37.9
Left ventricle	10	17.2
Abdominal aorta	9	15.5
Heart	5	8.6
Left atrium	3	5.2
Pulmonary Veins	3	5.2
Right atrium	1	1.7
Right ventricle	1	1.7
Inferior vena cava	1	1.7
Left iliac artery	1	1.7
Right iliac artery	1	1.7
Left carotid	1	1.7
Total	58	100
Unknown/not specified	42	

Michelassi F. Surgery. March, 1990.

The approach to ballistic embolism is based on the intensity and severity of its pathophysiological mechanisms. In 1949, Fritz conducted experiments seeking to understand the pathophysiology of a foreign body in the cardiovascular system.¹ He implanted metallic fragments in the heart of dogs.¹ After eight weeks, he noted that the shards were involved by the cardiac musculature.¹ Even those that were free at first showed no association with the formation of thrombi.¹

The initial trend of the approach to ballistics embolism is to indicate surgery in all cases.¹ It was believed

that the embolus would fatally cause complications.⁶ The morbidity and mortality rates were high.^{1,3} The projectile's removal often required large and complex surgeries. Over the years, several people who were victims of injuries by ballistic projectiles did not allow the surgical removal of the embolus. Some patients refused to face the proposed surgery.² In other cases of asymptomatic patients, the surgical removal of the projectile imposed unacceptable risks.² There was, then, the possibility of a non-operative treatment for this type of trauma. The non-operative conduct is permitted in cases of asymptomatic patients without peritoneal irritation and hemodynamically stable. Currently, the treatment of these patients, despite being in constant evolution, is still controversial¹⁻⁴ and a case-by-case management is recommended.^{1,3,4} The development of new diagnostic and therapeutic methods decreased mortality and morbidity rates,¹¹ however, it continues to be a potentially lethal trauma^{1,2,10} (Tables 3 and 4).

Table 3 - Indications for ballistic embolus removal from the pulmonary artery

Remove (if present)	Observe (if all are present)
Pulmonary Infarction	Without Pulmonary Infarction
Pulmonary Abscess	Without Pulmonary Abscess
Bronchial Erosion	Peripheral Location

Nagy KK. Am Surg. Dec, 1994.

Table 4 - Indications for the removal of ballistic embolus in the heart

Remove (if present)	Observe (if all are present)
The left side of the heart	Right side of the heart
Arrhythmias	Without arrhythmias
Valve dysfunction	No valve dysfunction
Association with thrombus formation	Not associated with thrombus formation
Endocarditis	Less than 5 mm
Cardiac neurosis	Firmly adhered
Contamination	Without contamination

Nagy KK. Am Surg. Dec, 1994.

The clinical history and physical examination are essential tools in the diagnosis of ballistic embolism. The clinical suspicion is the first step in the diagnosis.^{1,3} In general, the patient is presented clinically different than expected by the imaginary trajectory of the projectile.^{1,2,4} There is an inlet hole without an outlet hole, and the foreign body is found in an unexpected place, with discrepancies in clinical signs and symptoms.^{1,2,4}

Imaging methods are needed to confirm the diagnosis.¹¹ The projectile's location and study of lesions can be accomplished with simple x-rays, computerized tomography, echocardiography, ultrasound, arteriography, or venography.^{1,2,11} These exams are important preoperatively, and some in the peri-operative period, to demonstrate the possible embolus migration during patient handling.^{2,4} Some cases are diagnosed by chance during a surgical exploration. In general, patients will be operated due to peritoneal irritation or hemodynamic instability.

The treatment may be surgical or non-surgical. The best therapeutic option depends on a few factors such as: patient's clinical conditions, surgeon's experience, and institution's resources. The non-operative treatment is recommended for asymptomatic patients in most cases,^{2,4} and embolus surgical removal is recommended when there are symptoms or the possibility of complications such as embolization in risk areas.^{2,3} Generally, surgical indication applies more often to arterial emboli because they are more symptomatic.^{1,12,13} The choice of surgical procedure depends on the need to remove the ballistic embolus, its exact location, and clinical conditions of each patient. It is influenced by the size, shape, location, and potential bacterial contamination of the embolus.^{3,11,12} Projectiles smaller than 5 mm located in the peripheral circulation cause fewer problems in general (vascular obstruction, perforation) and are quickly incorporated by the vessels' walls.³ Emboli located proximally to the bifurcation of large vases must be removed because of the risk of causing segmental thrombosis and/or erosion of adjacent structures.^{3,14} The open surgery needs to be planned and can be performed through the following incisions: sternotomy, thoracotomy, laparotomy, thoraco-phreno-laparotomy, arteriotomy, venotomy.¹⁵

The improvement in minimally invasive techniques increasingly provides advances in the treatment of this trauma. The endovascular surgery gains space as morbidity and mortality rates decrease. It has been considered the first option for the treatment of mobile emboli.^{8,16} The most used technique is the removal through percutaneous basket (basket) or snare (snare) type catheters.^{8,16} The hemodynamics allows treatment with fewer complications and more effectiveness in embolus removal.^{1,3,16}

In the cases reported here, the diagnosis of embolism by ballistic projectile resulted from the clinical observation and evaluation of imaging exams. The in-

dication for surgery depended on the potential risks of the lesion, especially by vascular obstruction, and excellent results were achieved in all cases.

CONCLUSION

Penetrating trauma by firearm resulting in ballistic embolism is rare.¹⁷⁻¹⁹ Initially, it can lead to confusion in diagnosis due to discrepancies between signs and symptoms.^{2,20} There is a need for imaging exams to confirm the diagnosis and propose therapies. Surgical and non-operative treatments are indicated according to the patients' clinical picture and embolus' location and characteristics.^{1,17,19} Currently, the hemodynamic procedures constitute the first choice before the need of projectile removal when located in the intimacy of the vascular system.^{16,20} This treatment is less morbid in institutions with adequate resources and in the hands of experienced professionals.

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REFERENCES

1. Nagy KK, Massad M, Fildes J, Reyes H. Missile embolization revisited: a rationale for selective management. *Am Surg.* 1994; 60(12):975-9.
2. Mattox KL, Beall AC Jr, Ennix CL, DeBaakey ME. Intravascular migratory bullets. *Am J Surg.* 1979; 137(2):192-5.
3. Shannon FL, McCroskey BL, Moore EE, Moore FA. Venous bullet embolism: rationale for mandatory extraction. *J Trauma.* 1987; 27(10):1118-22.
4. Michelassi F, Pietrabissa A, Ferrari M, Mosca F, Vargish T, Moosa HH. Bullet emboli to the systemic and venous circulation. *Surg.* 1990; 107(3):239-45.
5. Kortbeek JB, Clark JA, Carraway RC. Conservative management of a pulmonary artery bullet embolism: case report and review of the literature. *J Trauma.* 1992; 33(6):906-8.
6. Barrett NR. Foreign bodies in the cardiovascular system. *Br J Surg.* 1950; 37(148):416-45.
7. Uflacker R, Lima S, Melichar AC. Intravascular foreign bodies: percutaneous retrieval. *Radiology.* 1986; 160(3):731-5.
8. Chen JJ, Mirvis SE, Shanmuganathan K. MDCT diagnosis and endovascular management of bullet embolization to the heart. *Emerg Radiol.* 2007; 14(2):127-30.
9. Corbett H, Paulsen EK, Smith RS, Carman CG. Paradoxical bullet embolus from the vena cava: a case report. *J Trauma.* 2003; 55(5):979-81.
10. Khanna A, Drugas GT. Air gun pellet embolization to the right heart: case report and review of the literature. *J Trauma.* 2003; 54(6):1239-41.
11. Bertoldo U, Enrichens F, Comba A, Ghiselli G, Vaccarisi S, Ferrari M. Retrograde venous bullet embolism: a rare occurrence-case report and literature review. *J Trauma.* 2004; 57(1):187-92.
12. Rehm C, Alspaugh JP, Sherman R. Bullet embolus to the right hepatic vein after a gunshot wound to the heart and its percutaneous retrieval. *J Trauma.* 1988; 28(5):719-20.
13. Layton TR, Stroh AM, Villella ER. Missile embolus of the portal vein. *J Trauma.* 1985; 25(11):1111-2.
14. Cysne E, Souza EG, Freitas E, Machado E, Giambroni E, Alves LPR, *et al.* Embolização de projétil de arma de fogo no sistema cardiovascular. *Rev Bras Cir.* 1982; 72(1):7-12.
15. Moraes Filho D, Schimit GTF, Tenório GOS, Sardinha WE, Silvestre JMS, Ramires ED. Embolia arterial periférica por projétil de arma de fogo em civis: diagnóstico confirmado pelo ultrassom vascular. *J Vasc Bras.* 2012; 11(1):67-72.
16. Wolf F, Scherthaner RE, Dirisamer A, Schoder M, Funovics M, Kettenbach J, *et al.* Endovascular management of lost or misplaced intravascular objects: experiences of 12 years. *Cardiovasc Intervent Radiol.* 2008; 31(3):563-8.
17. Yamanari MGI, Mansur MCD, Kay FU, Silverio PRB, Jayanthi SK, Funari MBG. Embolia pulmonar por projétil de arma de fogo: relato de caso. *Radiol Bras.* 2014; 47(2):128-30.
18. Chapman AJ, McClain J. Wandering missiles: autopsy study. *J Trauma.* 1984; 24(7):634-7.
19. Van Way CW. Intrathoracic and intravascular migratory foreign bodies. *Surg Clin North Am.* 1989; 69(1):125-33.
20. Carter CO, Havens JM, Robinson WP, Menard MT, Gatesa JD. Venous bullet embolism and subsequent endovascular retrieval – A case report and review of the literature. *Int J Surg Case Rep.* 2012; 3(12):581-3.