European Journal of Radiology 82 (2013) e120–e141

Contents lists available at SciVerse ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Review

Imaging of nonthrombotic pulmonary embolism: Biological materials, nonbiological materials, and foreign bodies

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ARTICLE INFO

Article history:
Received 23 May 2012
Received in revised form 6 September 2012
Accepted 12 September 2012

Keywords:
Nonthrombotic pulmonary embolism
Amniotic fluid embolism
Fat embolism
Tumor embolism
Cement embolism
Gas embolism

ABSTRACT

Nonthrombotic pulmonary embolism is defined as embolization to the pulmonary circulation caused by a wide range of substances of endogenous and exogenous biological and nonbiological origin and foreign bodies. It is an underestimated cause of acute and chronic embolism. Symptoms cover the entire spectrum from asymptomatic patients to sudden death.

In addition to obstruction of the pulmonary vasculature there may be an inflammatory cascade that deteriorates vascular, pulmonary and cardiac function. In most cases the patient history and radiological imaging reveals the true nature of the patient's condition.

The purpose of this article is to give the reader a survey on pathophysiology, typical clinical and radiological findings in different forms of nonthrombotic pulmonary embolism. The spectrum of forms presented here includes pulmonary embolism with biological materials (amniotic fluid, trophoblast material, endogenous tissue like bone and brain, fat, *Echinococcus granulosus*, septic emboli and tumor cells); nonbiological materials (cement, gas, iodinated oil, glue, metallic mercury, radiotracer, silicone, talc, cotton, and hyaluronic acid); and foreign bodies (lost intravascular objects, bullets, catheter fragments, intraoperative material, radioactive seeds, and ventriculoperitoneal shunts).

1. Introduction

Nonthrombotic pulmonary embolism (NTPE) is defined as embolization to the pulmonary circulation caused by a variety of nonthrombotic embolic agents. The spectrum of NTPE constitutes an interesting and clinically relevant field. Unlike pulmonary thromboembolism as a frequent cause of morbidity and mortality, NTPE is less common.

However, it is an underestimated cause of acute and chronic embolism [1–5] that requires a different therapeutic approach compared with thrombotic pulmonary embolism. Furthermore, almost all NTPE with nonbiological material are of iatrogenic origin and associated with certain procedures (Table 1).

Symptoms cover the entire spectrum from asymptomatic patients to sudden death. The clinical appearance of NPTE is similar to that of thrombotic pulmonary embolism in most cases. Symptoms include dyspnea, tachycardia, breast pain, cough, sometimes hemoptysis, cyanosis, anxiety and syncope. D-dimers are non-diagnostic because coagulation and fibrinolytic pathway are

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http://dx.doi.org/10.1016/j.ejrad.2012.09.019

Table 1
Most common causes of different forms of nonthrombotic pulmonary embolism.

Iatrogenic[a]	Traumatic	Other
• Bone and tissue embolism (also traumatic) • Iodinated oil and glue embolism • Radiotracer embolism • Radioactive seed embolism • Cement embolism • Gas embolism (also traumatic) • Pacemaker lead embolism • Lost intravascular objects • Ventriculoperitoneal shunt embolism • Intraoperative material embolism • Catheter embolism • Silicone embolism • Hyaluronic acid embolism	• fat embolism • bone and tissue embolism (also iatrogenic) • gas embolism (also iatrogenic) • bullet embolism	• peripartal: amniotic fluid emoblism • oncologic: tumor embolism • infectious: septic embolism, hydatid embolism • suicidal: mercury embolism • drug abuse: talc/cotton embolism

[a] Includes direct and long-term effects of legal and illicit medical procedures.

not activated. This finding may lead to misdiagnosis. However, massive pulmonary embolism – regardless of its origin – is likely to cause right ventricular injury. This will result in increased concentrations of troponin and natriuretic peptides [6].

In most cases the patient's history and radiological imaging reveal the true nature of the patient's condition. In some types of NTPE – including embolism with fat, amniotic fluid, and silicone – pulmonary symptoms are typically accompanied by signs of intracerebral and cutaneous embolism.

NTPE can be caused by a wide range of substances of endogenous and exogenous biological origin (Table 2), by substances of nonbiological origin (Table 3) and by foreign bodies (Table 4).

Emboli can either be applied/get lost inside the vessel or migrate transvascular from an extravascular site into the venous system. For example, many NTPE with biological material are transvascular. Cases of transvascular migration of nonbiological material often present a diagnostic challenge because the migration process can take weeks to years. In many cases the exact mechanisms of transvascular migration remain unclear [1–5]. A pressure gradient towards the venous system and an erosion of the vessel walls are commonly suggested. NTPE with nonbiological material and transvascular migration include silicone embolism, cement embolism, radioactive seed embolism, bullet embolism, embolism with ventriculoperitoneal shunts and intraoperative material.

In radiological imaging NTPE occurs as macro- or microembolism. Macroembolic NTPE presents as visible obstruction of pulmonary arteries by detectable foreign material. It is seen in hydatid embolism, glue embolism, gas embolism, catheter embolism, pacemaker lead embolism, cement embolism, embolism with angiographic and intraoperative material, bullet embolism, and ventriculoperitoneal shunt embolism.

In many forms of nonbiological macroembolism the embolising material is hyperdense. In contrast enhanced CT examinations the embolising material may remain undetected because of the bright intraarterial contrast. Detection may be easier in bone window [7]. Dense structures like surgical sutures or calcified lung granulomas may mimic macroembolism. However, these structures are not found inside pulmonary arteries.

In microembolism the embolising material is not directly seen on CT images and the diagnosis rests on the parenchymal findings. Indirect sings of obstruction include pulmonary edema, infarction, empyema or pulmonary hypertension. It is found in fat embolism, amniotic fluid embolism, septic embolism, bone and tissue embolism, talcum granulomatosis, radiotracer embolism, and silicone embolism. Tumor embolism often presents as microembolism; however in some cases it progressively develops into macroembolism.

Radioactive seed embolism and mercury embolism both present a special form as the embolising agent is straightforward visible due to its high density. However, the small size particles are located mostly in very small pulmonary arteries. The obstruction of these arteries cannot be seen on CT images.

Table 2
Mechanism, patient history and typical symptoms of pulmonary embolism with biological materials.

Type	mechanism	patient history	Symptoms[a]
Amniotic fluid and trophoblast embolism	mechanical obstruction by fetal cells/lanugo/meconium and inflammatory reaction/vasospasm/disseminated intravascular coagulation/decreased coronary flow due to metabolites of arachidonic acid (chemical pneumonitis)	during or after delivery	cerebral symptoms
Bone and tissue embolism	mechanical obstruction by endogenous or external tissue fragments	bone marrow transplantation or massive trauma	asymptomatic
Fat embolism	mechanical obstruction by fat globules and inflammatory reaction to free fatty acids (chemical pneumonitis)	after fractures or soft tissue trauma	cerebral and cutaneous symptoms (fat embolism syndrome)
Hydatid embolism	mechanical obstruction by hydatid cysts	cardiac or hepatic echinococcosis	typically hemoptysis
Septic embolism	mechanical obstruction by a thrombus containing microorganisms causing an inflammatory reaction	focus of extrapulmonary infection	fever and signs of infection
Tumor embolism	progressive mechanical obstruction with tumor cells	oncological patient	emboli resistant to fibrinolytic therapy; chronic/progressive course

[a] Beyond that of typical thrombotic embolism.