Imaging evaluation of hemoptysis: what the on-call radiologist should know

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Learning objectives

The learning objectives of this educational exhibit are:

- To recognize the possible imaging presentation of hemoptysis.
- To review and illustrate the systemic and pulmonary vascular anatomy relevant in the setting of hemoptysis.
- To recognize treatment options currently available in the management of hemoptysis and how the imaging findings influence the therapeutic decision.
- To review the various aspects of endovascular management of hemoptysis.
Background

Hemoptysis is not an unusual indication for a patient to be sent from the emergency room to the imaging department, given the prevalence of chronic inflammatory lung diseases, pulmonary infection, tuberculosis and cystic fibrosis.

The lungs are prone to various imaging presentations of disease leading to hemoptysis, depending on the whether the pulmonary or systemic circulations are involved.

The on-call radiologist should be able not only to recognize the imaging findings of this entity, but also be acquainted with available treatment options. Imaging findings are directly implied in the therapeutic decision even if active bleeding is only identified in about half the cases.

The emergence of arterial embolization has allowed potential life-saving control over many bleeding lesions and even a therapeutic bridge for lung transplant, as in patients with cystic fibrosis. It is a powerful interventional tool that should be understood by the on-call radiologist, as it will be highly influenced by the patient's initial imaging evaluation.

Massive hemoptysis is defined as a volume greater than 300ml of blood loss into the tracheobronchial tree in 24 hours, at a rate that is life threatening.

With conservative management, massive hemoptysis has a 50 to 85% mortality rate.

Etiology of hemoptysis

Airways diseases (the most common source of hemoptysis)

- Inflammatory diseases, such as bronchitis (acute or chronic) or bronchiectasis (e.g. cystic fibrosis)
- Neoplasms, including primary bronchogenic carcinoma, endobronchial metastatic carcinoma, or bronchial carcinoid
- Foreign body
- Airway trauma.
- Fistula between a vessel and the tracheobronchial tree.

Pulmonary parenchymal diseases

- Infection (e.g. tuberculosis, pneumonia, aspergilloma, and lung abscess)
- Inflammatory or immune disorders (e.g. Goodpasture's syndrome, idiopathic pulmonary hemosiderosis, lupus pneumonitis, and Wegener’s granulomatosis)
• Genetic disorders of connective tissue (e.g. Ehlers-Danlos syndrome, vascular type)
• Coagulopathy
• Iatrogenic, especially due to either percutaneous or transbronchial lung biopsy

Pulmonary vascular disorders

• Pulmonary embolism
• Pulmonary arteriovenous malformation
• Elevated pulmonary capillary pressure, as seen with mitral stenosis or significant left ventricular failure.
• Iatrogenic (e.g. pulmonary artery perforation from a Swan-Ganz catheter)

Cryptogenic (up to 30 percent of patients with hemoptysis)

Other

• Cocaine-induced pulmonary hemorrhage
• Catamenial hemoptysis due to intrathoracic endometriosis
• Treatment with Bevacizumab or endothelial growth factor

Pathology

Bronchial-pulmonary arterial anastomoses are present in the normal lungs and can be identified in bronchial arteriography. These anastomoses help explain why lung infarction is infrequent in pulmonary arterial occlusive disease. Because of these anastomoses, arterial embolization in the setting of hemoptysis needs to include both the bronchial artery and the bronchial-pulmonary anastomoses.

These anastomoses in the peribronchial inflamed tissue and are notably more fragile. Because the bronchial arteries are exposed to systemic arterial pressure, they are prone to rupture and cause hemoptysis.

Dilation of the bronchial arteries is a secondary phenomenon caused by the increase of flow as a result of pathologic shunts between the systemic and the pulmonary arterial beds. Understanding this as a secondary phenomenon is important because the embolization procedure should be directed to the shunts and not to the dilated bronchial arteries.

Non-bronchial transpleural systemic neovascularization is also a common cause of hemoptysis. These include intercostal arteries, the inferior phrenic artery, thoracic branches of the axillary and subclavian arteries and internal mammary arteries. Fistulas between the systemic and the pulmonary arteries will always lead to flow from the systemic arteries to the pulmonary arteries due to the pressure differences. Filling of the
pulmonary veins through the lung parenchyma capillaries will subsequently occur, but it is important to realize the there are no anastomoses between the systemic arteries and the pulmonary veins and as such, no right-to-left shunt exists and there is no risk of systemic embolization from arterial embolization procedure.

Site of bleeding

- Bronchial-pulmonary anastomoses
- Non-bronchial transpleural anastomoses
- Pulmonary artery branches

The strict differentiation between bronchial and pulmonary bleeding of not of particular use and most bronchial bleeding originates from an abnormal pulmonary arterial branch.

Anatomy

The bronchial arteries generally originate at the level between the superior border of T5 and the inferior border of T6.

The right bronchial artery usually arises from the lateral-posterior side of the aorta, in 90% of cases from a right intercostal-bronchial trunk.

The left bronchial artery usually arises from the lateral-anterior side or from the anterior side of the aorta. There are usually two left bronchial arteries and variant origins are common, including the inferior surface of the aortic arch or the thyrocervical trunk. A common trunk for the origins of both the right and left bronchial arteries is also frequent.

The bronchial arteries are responsible for the vascularization of the bronchial tree, the vasa vasorum (in conjunction with the pulmonary arteries and the aorta), the lower third of the esophagus and the visceral pleura.

These arteries can also feed other structures, through myocardial branches and importantly the anterior spinal artery.

Initial management of hemoptysis

Evaluation of hemoptysis

- The initial imaging study is the chest radiograph
- Abnormal findings may be suggestive of specific causes of hemoptysis (e.g. neoplasm, focal infection, mitral regurgitation)

Further evaluation is directed toward the suspected diagnosis
• Fiber optic bronchoscopy is particularly useful for diagnosing bronchitis and mucosal lesions (e.g. Kaposi’s sarcoma)
• HRCT can identify virtually all tumors seen by bronchoscopy as well as several which were beyond bronchoscopic range, as well as bronchiectasis and aspergillomas.

If the diagnostic criteria of massive hemoptysis are met, further measures should be taken

• Selective intubation of the non-bleeding lung and placing the patient with the bleeding side dependent (to protect the non bleeding lung from filling with blood)
• Bronchofibroscopy with the intent to place an intrabronchial balloon for acute bleeding control
• Bronchial angiography once the patient has established
Fig. 1: Initial chest radiogram of a patient with haemoptysis and no prior known medical history. Note the opacity on the right.

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Fig. 2: Hemoptysis in a patient with bronchiectasis and parenchymal haemorrhage.

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Fig. 3: Hypertrophied bronchial arteries on CT

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Fig. 4: Bronchial artery angiography Note hypertrophied bronchial artery. The bronchial arteries dilate as a secondary finding. They are not the cause of hemoptysis and should not be the target of embolisation.

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**Fig. 5:** Non-bronchial trans-pleural systemic arteries coming from the left subclavian artery. Note pulmonary venous filling.

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**Fig. 6:** Fiberoptic bronchoscopy of a patient with hemoptysis Right: Note the arterial jet into the bronchial tree

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Procedural details of arterial embolization of the bronchial arteries

Approach

Diffuse arterial disease most frequent presentation in the setting of hemoptysis. In these cases, a bronchial artery approach is preferred because it allows good visualization of the pulmonary arteries.

Focal lung anomalies should be carefully sought out.

In case of focal arterial disease, the preferred approach tends to be the pulmonary arteries, even if it does not allow for visualization of the bronchial arteries. However, in the presence of a focal lung anomaly, this tends to be the most frequent site of bleeding, even in the setting of diffuse disease.

One exception if the case of pulmonary aneurysmatic disease, previously detected at thoracic angioCT. Due to the bronchial-pulmonary shunt, bronchial angiography is more helpful than pulmonary angiography. These aneurysms are increasingly recognized as being more frequent than initially though and most are pseudo-aneurysms and place the patient at increased risk of catastrophic hemoptysis.

The Rasmussen aneurysm is the result of erosion of a peripheral arterial branch inside a cavity (e.g. pulmonary tuberculosis, sarcoidosis, aspergilloma). These are frequently too small to be adequately identified at angioCT.

In the setting of localized disease with a shunt between the bronchial artery and a pulmonary branch, there is often some irregularity in the pulmonary arterial branches, particularly around aspergillomas.

A systemic-pulmonary arterial shunt is very common. If it is very localized, it could allow for a combined embolization of both the systemic and the pulmonary side in a single procedure and in asymptomatic patients.

In diffuse disease, a pulmonary arterial approach should be considered if a previous embolization from a bronchial approach leads to early recurrent hemoptysis.

When early recurrent hemoptysis after technically successful embolization occurs, a mixed approach from both the systemic and the pulmonary arterial beds could allow to close the 'front and back doors'.

Intent of the procedure
The intent of the embolization procedure is not to cure the vascular anomaly but to the abnormal arterial branch to thrombose by reducing the perfusion pressure to which the abnormal friable vessel is submitted. The embolization does not fully prevent recurrent hemoptysis and can be repeated if needed.

Mortality from massive hemoptysis is substantially reduced by surgery. However, most patients with massive hemoptysis are not surgical candidates due to significant, often bilateral, lung disease and enlarged transpleural vessels.

**Patient selection and pre-procedure management**

Patient selection and pre-procedure management should take in mind the underlying etiology.

Patients with known chronic inflammatory lung disease could be offered a thoracic CT, but this imaging study is not essential and unless it is done in a state-of-the-art equipment with careful protocol, it is most often useless. Getting a thoracic CT should not delay the embolization procedure in case of active bleeding. However, it can be useful to depict the vascular anatomy, the presence of enlarged bronchial arteries and the presence of pulmonary aneurysmatic disease.

Pulmonary aneurysmatic disease is more frequent than initially though and can have catastrophic outcomes. State-of-the-art contrast-enhanced CT can be useful in detecting pulmonary artery aneurysms, even small ones, but its diagnostic acuity if often degraded by marked lung parenchyma abnormalities.

Concerning patients with no known chronic inflammatory lung disease but with abnormalities at chest radiograms, if these are suggestive of chronic inflammatory lung disease and / or aspergilloma, should be managed as if the disease was known. If the chest radiogram is suggestive of malignancy, than embolization rarely has a therapeutic benefit and these patients should be further studied by CT or optical Bronchofibroscopy.

In patients with no known chronic inflammatory lung disease and no abnormality in the chest radiogram should be further studied by CT of optical bonchofibroscopy in search of signs of chronic inflammatory lung disease or malignancy. Even if the thoracic CT is normal, massive hemoptysis can still occur, but bronchial angiography and embolization is rarely of any use. The CT scan should be state-of-the-art because hypertrophied non-bronchial systemic arteries are easy to miss.
Patients with pulmonary arterial-venous vascular malformation pose specific problems because, unlike systemic-pulmonary arterial anastomoses frequently seen, there is a real right to left shunt with the risk of systemic embolization.

**Technical aspects of the embolization procedure**

The initial aortography should be performed with a pigtail catheter positioned just distal to the emergence of the left subclavian artery and using an injector. Positioning the pigtail to proximal (i.e. in the ascending aorta) could obscure the origins of the bronchial arteries.

After identification of enlarged bronchial arteries, they can be selectively catheterized using a 5F Cobra catheter (other shapes like the Sidewinder can also be useful). A microcatheter can be advanced just proximal to the abnormal vessels, but not to far as it could induce vasospasm and place the catheter in a wedged position. Wedged catheter position should be avoided as it could lead to refluxing of the embolic agents to non-target circulation (e.g. to the anterior spinal artery).

Distal occlusion should be obtained using particles (PVA), starting with sizes of 150 - 250 µm (1 vial of PVA diluted in 20ml of contrast agent). If enlarged arteries are still seen, a second trial with particles of size 350 - 500 µm should be performed. Coils should be avoided unless to protect normal branches, as coils tend to promote the development of collaterals distal to the site of occlusion. Liquid sclerosants should also be avoided due to the risk of systemic embolization.

**Complications**

Non-target embolization is the most dreaded complication, especially when taking into account the possible collateral pathways present.

A wedged catheter position and vasospasm should be avoided and the injection of the embolic agent should be slow and controlled fluoroscopically. As always, it should be remembered that the intent of the embolization is not to cure but to palliate, reducing the perfusing pressure to the abnormal vessels just enough to allow it to thrombose. A little more is often a little too much.

- Anterior spinal infarction infarction after embolization

Is rare but can result from non-target embolization to the anterior spinal artery (artery of Adamkiewicz), leading to paralysis.
It can also happen in cases of transverse myelitis caused by forceful contrast agent injection.

It is very important to position the catheter tip beyond the origin of this artery.

Other complications include:

- Chest pain and dysphagia

Usually transient and results commonly from non target embolization of the intercostal arteries and esophageal arterial branches

- Subintimal dissection

Involves the aorta and the bronchial vessels and is of subclinical and of no consequence. It happens due to guidewire manipulation.

**Outcomes**

Massive hemoptysis can be immediately controlled by endovascular procedure in about 75 - 90% of cases. Of technically and clinically successful cases, recurrent hemoptysis is still expected in about 20% in the course of 6 months and probably more over a longer period of follow-up.

Most unsuccessful cases are related to the inability to identify the abnormal bleeding vessel.

**Follow up**

A neurological exam should be performed before and after the procedure to evaluate the occurrence of non-target embolization of the spinal cord.

Clinical follow-up should help identify recurrence due further recruitment of collaterals. Especially in non-malignant etiologies, like in Cystic Fibrosis, repeat endovascular treatment may be necessary.
Images for this section:

Fig. 7: Common variation of the bronchial arteries

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Fig. 8: Hypertrophied bronchial artery on angiography

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**Fig. 9:** Rassmussen aneurysm in a patient with hemoptysis, pulmonary tuberculosis and bronchiectasis

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Fig. 10: Right: Left Internal mammary artery anastomosing with a pulmonary vascular malformation. Notice the pulmonary venous drainage. Left: Result after successful particulate and coil embolisation. Pulmonary MAV is excluded.

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Fig. 11: Artery of Adamkiewitz or artery radicularis magna. Non target embolisation of this artery may result in spinal cord infarction and paralysis

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Conclusion

The dual circulation of the lungs allows for a multitude of imaging presentations in patients with hemoptysis. Even if active bleeding is only seen in about half of the cases, telltale signs as hypertrophied bronchial and systemic arteries should alert the radiologist to the potential point of bleeding. This initial evaluation is crucial to guide therapeutic decision and planning, as well as avoiding serious neurologic complications from non-target embolization.
References

Anterior Spinal Cord Infarction following Bronchial Artery Embolization

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