Life-threatening Hemoptysis: Role of MDCT angiography

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Learning objectives

# To know the pathophysiologic features and the most important causes of life-threatening hemoptysis.

# To consider the clinical context of the patients in order to focus the evaluation of the different vessels potentially involved (bronchial and nonbronchial systemic arteries, pulmonary arteries).

# To evaluate the role of MCDT angiography in the identification of the bleeding site and the vessels causing massive hemoptysis.

Background

- Hemoptysis is defined as the expectoration of blood originating from the tracheobronchial tree or pulmonary parenchyma.
- The quantification of blood is difficult from the clinical point of view, so the term more useful is **life-threatening hemoptysis (LTH)**, to define a situation where there is an immediate risk to the life of the patient, which is the airway compromise; the clinical significance of an episode of hemoptysis should take into account not only the volume of expectorated blood, but also the effects on the patient's respiratory and cardiovascular reserves.
- Life-threatening hemoptysis is rare; conservative management carries a mortality rate of 50-100%.
- Urgent surgery in patients with active bleeding is associated with high morbidity and mortality, from this **bronchial artery embolization (BAE)** is currently the treatment of choice in most cases.
- The initial evaluation of patients with hemoptysis is directed to identify the origin and underlying cause of the bleeding.
- First exploration of a patient with LTH is a conventional radiography (which often is useful in localizing the bleeding area *(fig. 1. a-f)*, followed by a CT angiography of the chest. Currently in our hospital are not made urgent bronchoscopy studies at these patients.
- Pretreatment realization of MDCT angiography allows a detailed evaluation of the mediastinum and pulmonary parenchyma, resulting in angiographic studies of the thoracic vasculature (systemic and pulmonary) and upper abdomen, which are useful for planning the embolization, or surgery in certain cases.

Pathophysiologic features and Causes of hemoptysis

- The lungs are supplied by a dual arterial vascular system:
(1) **pulmonary arteries**, which account for 99% of the arterial blood supply to the lungs and take part in gas exchange; and

(2) **bronchial arteries**, which are responsible for providing nourishment to the supporting structures of the airways, but do not normally take part in gas exchange.

- Histologically, the two systems are connected by anastomoses between the systemic and pulmonary capillaries.
- Conditions causing **decrease of pulmonary circulation** and maintained ischemia (eg, chronic thromboembolism), the bronchial circulation responds with a focal vascular **hypertrophy** and **proliferation** through the anastomotic channels, to replace the pulmonary circulation.
- The **neoplastic disease** and **chronic inflammation** (eg, bronchiectasis and chronic infections), by angiogenic growth factors, produce **neovascularization** and **increased systemic circulation**.
- These neoformed and hypertrophied systemic vessels are usually very fragile and are exposed to systemic pressure, so they tend to break at its distal portion (capillary) into the bronchial lumen or alveoli, causing hemoptysis.
- The **bronchial circulation** is the most frequent source of hemoptysis (90% of cases), but **nonbronchial systemic arteries**, as well as **pulmonary arteries**, on rare occasions, may also contribute.
- The underlying **causes** of hemoptysis vary depending on the geographic location of the study, the prevalence of tuberculosis and the use of CT studies. In our area the most common causes of LTH are bronchiectasis, tuberculosis and its sequelae and lung cancer. **Table 1** shows the main causes of LTH.

**Images for this section:**
Figure 1 a)-f). Patient with Chronic pulmonary thromboembolism. a) Chest radiograph shows opacities in the right pulmonary base. b) TC (lung window) shows ground-glass areas in the right middle and right lower lobe corresponding to the bleeding. c) and d) CT images showing signs of Chronic thromboembolism a big eccentric thrombus in the right pulmonary artery (arrowheads) and linear densities in lower lobes branches corresponding with residua bands (arrows in d). e), f) shows enhancing dot-like or tubular images with attenuation similar to that of the aorta corresponding to hypertrophied bronchial arteries (arrows).

Fig. 1: Fig. 1. a-f.
Imaging findings OR Procedure details

Multi-Detector Row CT -Technique and Data Manipulation

- The imaging parameters used are: 120 kV, 70-120 mAs (variable values according caredose ®), rotation time of 0.42 s, 0.75 mm collimation and "pitch" of 0.85. The thickness of image reconstruction is 1 mm, with an interval of 0.7 mm.
- The acquisition is performed with the patient in the supine position at maximal inspiration during a single breath-hold, in a craniocaudal direction from the base of the neck to the middle third of the kidneys (renal arteries level), to include the supraaortic great vessels and the infradiaphragmatic arteries.
- 100 ml of nonionic iodinated contrast was administered intravenously at a rate of 4 mL/ s
- The axial sections will be useful for detecting the origin of the systemic arteries. Reconstructions in maximum intensity projection (MIP) will be essential to display the tortuous course of these arteries.
- The reconstructions in the coronal plane are better suited for analysis of the intercostal and internal mammary arteries;
- The axial reconstructions are ideal for demonstrating inferior phrenic arteries and branches from the celiac axis.
- The reconstructions in the oblique sagittal plane are also useful for demonstrating the mammary and phrenic arteries.
- The degree of obliquity and the thickness of the reconstructions we fit in each case. The MIP reconstructions of the pulmonary arteries in different planes, also will be necessary in suspected pathology of them.

Assessment of the lung parenchyma

- The most common signs of bleeding in the lung parenchyma are centrilobular nodules, ground-glass opacities and / or condensation (Fig. 1. b, 2). Clots can also be observe inside the bronchi, which may secondarily produce atelectasis (Fig. 2).

If the damage is extensive and bilateral, the multiplanar reconstructions are useful in assessing bleeding zonal predominance.
- When there is cavities, can be filled with blood (Fig. 3) and occasionally may identify hyperdense areas by the clots.
- The blood clots may simulate nodules or masses, which is why it is sometimes advisable to perform follow-up CT scan several weeks after the episode of hemoptysis, to see the evolution of suspicious images (Fig. 4). Rarely extravasation of contrast can be seen in the bronchial lumen.
Assessment of the vascularization

Bronchial arteries

- In 90% of cases, the bronchial systemic arteries are the source of hemoptysis.
- Bronchial arteries are considered those that go to the lungs through the pulmonary hilum, along the bronchial tree.

The evaluation of bronchial arteries must detect:

a) **The site of the ostium** of the bronchial artery (or arteries), to assess whether they are orthotopic or ectopic.
b) **Description of the output in the aortic wall** (anterior, posterior, left or right side).

c) **The bronchial artery diameter**.
d) **The total number of pathological bronchial arteries on each side**.

- The orthotopic bronchial arteries are those having an origin in the descending thoracic aorta at the level of the vertebral bodies T5-T6 (approximately in the region of the carina).
- The bronchial arteries that origin outside the area between T5-T6 are called **ectopic bronchial arteries**.
- The systemic arteries that do not reach the lung parenchyma through the pulmonary hilum are called **nonbronchial systemic arteries**.
- The orthotopic bronchial arteries are highly variable in their anatomical origin, branching pattern and course (**Fig. 5**).
- The most constant vessel is the right intercostobronchial trunk (ICBT), present in 90% of cases (**Fig. 1. g-i**).
- In MDCT angiography the bronchial arteries are identified in the posterior mediastinum as dots or lines of increased attenuation (almost imperceptible if not hypertrofidas), around the main bronchi, esophagus and aortopulmonary window (**Fig. 1. e,f**); MIP reconstructions are essential in different planes to represent its origin and courses (**Fig. 1. g**).
- A diameter of more than 2 mm in origin of bronchial artery is considered pathological and oriented toward the artery to be embolized; unfortunately there is a poor correlation between the size of the artery and the risk of bleeding.
- Another important aspect is the **traceability** of bronchial artery causing hemoptysis.
• The bronchial artery aneurysms are rare entities that may arise within
the mediastinum or from the intrapulmonary portion of the artery. MDCT-
angiography can show them (Fig. 7).
• The ectopic bronchial arteries have a prevalence between 8.3% and 35%.
• The most frequent ectopic origins are: the concavity of the aortic arch (74%),
the subclavian artery ipsi-or contralateral (10.5%) (Fig. 6), the abdominal
aorta (8.5%), the ipsilateral brachiocephalic trunk (2%), the ipsilateral internal
mammary artery (2.5%) and the trunk thyrocervical ipsilateral (2.5%).

Nonbronchial systemic arteries

• The nonbronchial systemic arteries are involved in 41% -88% of cases of
hemoptysis.
• May constitute the primary cause of bleeding or be an additional cause
of bronchial arteries bleeding.
• They enter the lung parenchyma through the pleura or the inferior pulmonary
ligament and its course is not parallel to the bronchi.
• Can originate from the: intercostal arteries (most often involved), branches
of the supaortic great vessels (brachiocephalic artery, subclavian
arteries, thyrocervical and costocervical trunks), axillary arteries, internal
mammary arteries and aortic infradiaphragmatic branches (inferior
phrenic arteries, gastric arteries and the celiac trunk).
• The presence of abnormally dilated and tortuous arteries within the
extrapleural fat, associated with pleural thickening (greater than 3 mm)
and adjacent lung parenchyma abnormalities (bronchiectasis, tuberculosis
sequelae), should make us suspect their involvement in hemoptysis (Fig. 6,
8).
• Once the site of bleeding is located in MDCT-angiography, a systematic
search of the nonbronchial arteries that can potentially vascularize this area
should be performed:

- the inferior phrenic artery (Fig. 9) (lower lobes and inferior segment of the
lingula),

- the intercostal arteries (posterior pleura),

- the internal mammary artery (anterior segment of the upper lobes, middle
lobe and lingula) and

- branches of the subclavian and axillary arteries (the pulmonary apex).

Failure to recognize these systemic arteries can lead to early recurrence of
hemoptysis after successful BAE.
• We consider also congenital lung malformations with systemic irrigation,
rare entities that may cause LTH, such as:
• **bronchopulmonary sequestration** (mass of nonfunctioning lung tissue, usually without connection to the normal bronchial tree) *(Fig. 10)* and
• **normal lung systemic irrigation (ISPN)**, a purely vascular anomaly, usually a single systemic artery irrigates a normal lung portion.

  In both cases, the anomaly usually affects the **lower lobes**, the systemic artery often arise from the **abdominal aorta** (entering into the lung via inferior portion of the pulmonary ligament), and the venous drainage is via the pulmonary veins.

• The possibility of **congenital malformation** as a cause of LTH may be suspected especially in **young patients without known previous lung disease** *(Fig 10)*.

**Pulmonary arteries**

• Assessment of the thoracic vasculature should always include the pulmonary arterial circulation.

• Hemoptysis originating from the pulmonary artery represents 10% of cases of LTH.

• The aims of the evaluation is identifying **aneurysms** or **pseudoaneurysms** (PA, artery dilation that not includes all layers of the wall) of the pulmonary arteries, entities that are visualized on MDCT-angiography as saccular or fusiform dilatation of the pulmonary arteries filled with contrast, simultaneously with the rest of the pulmonary arteries.

• Visualization of a pulmonary artery branch in the inner aspect or within the wall cavity, even without finding a PA, suggests the possibility of a pulmonary artery origin of hemoptysis *(Fig. 3)*.

• MDCT-angiography with MIP and multiplanar reconstructions allow anatomic localization and the feeding artery of PA.

• Sometimes the distal PA are not visible in the global or lobar pulmonary arteriography, and are only displayed in superselective angiography of the pulmonary arteries *(Fig. 11. e,f)*.

• Potential **causes of pulmonary arterial** origin hemoptysis are numerous and include:

  - **Pulmonary necrosis** *(Fig. 11)*
    
    • Destructive or inflammatory lung process (infectious or cancer) destroy adjacent lung, weaken the arterial wall, or eroding any vessel in its vicinity, causing a PA.

  - **Vasculitis**
    
    • Mainly associated with Behçet's disease and Hughes-Stovin syndrome.
    • Causing pulmonary artery **aneurysms**, thrombosis and surrounding inflammation.
- **Traumatic**

  - Iatrogenic causes, mainly **malpositioned Swan-Ganz catheter**, can developed in pulmonary artery **pseudoaneurysm**, that is contained in the adventitia and sometimes by thrombosis. **Penetrating trauma** can cause it as well.

- **Pulmonary Arteriovenous Malformations.**

  - Mainly congenital, produce abnormal communication between pulmonary arteries and pulmonary veins. Most of patients have hereditary **Rendu-Osler Syndrome**.

**Rasmussen aneurysms** is a pulmonary arterial pseudoaneurysms that develops in pulmonary vessels along the wall of tuberculous cavities.

- granulation tissue replaces external layers of the vessel wall, with erosion of the artery and pseudoaneurysm formation.

- usually involves the **upper lobes** in the setting of reactivation tuberculosis

**Causes of rebleeding**

- After embolization immediate control of hemoptysis is achieved in 73-99% of patients.

- The recurrence is not uncommon, occurring in 10-53% of cases.

- Early recurrence, within the first few weeks of embolization, is caused by incomplete occlusion of the vessels involved, which may be due to the extensive nature of the underlying cause, or incomplete search for all abnormal vessels.

- Late rebleeding occurs due to recanalization of previously embolized vessels, embolization of other vessels not involved, or revascularization of collateral circulation secondary to persistence or progression of the underlying pathology.

For these reasons it is important to identify and embolize all vessels that may contribute to abnormal irrigation, including any nonbronchial systemic or lung artery.

**Images for this section:**
**Figure 1 a)-f).** Patient with Chronic pulmonary thromboembolism. 

a) Chest radiograph shows opacities in the right pulmonary base. 
b) CT (lung window) shows ground-glass areas in the right middle and right lower lobe corresponding to the bleeding. 
c) and d) CT images showing signs of Chronic thromboembolism: a big eccentric thrombus in the right pulmonary artery (arrowheads) and linear densities in lower lobes branches corresponding with residua bands (arrows in d). 
e), f) shows enhancing dot-like or tubular images with attenuation similar to that of the aorta corresponding to hypertrophied bronchial arteries (arrows).

**Fig. 1:** Fig. 1. a-f.
Figure 1 g-i. Patient with Chronic pulmonary thromboembolism. g) coronal MIP shows hypertrophy of a right intercostobronchial trunk (white arrows) and a left common bibronchial trunk (black arrows). h), i), angiography confirms the CT findings showing an hypertrophied right intercostobronchial trunk (white arrows) the intercostal portion is also seen (thin arrows), i) showing the left common bibronchial trunk (arrows).

Fig. 2: Fig. 1. g-i.
<table>
<thead>
<tr>
<th>Table 1</th>
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<tbody>
<tr>
<td>Causes of life-threatening hemoptysis</td>
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<tr>
<td>1. Acquired</td>
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<tr>
<td>A. Chronic inflammation of the lung parenchyma</td>
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<tr>
<td>- Bronchiectasis</td>
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<tr>
<td>- Cystic fibrosis</td>
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<tr>
<td>- Chronic bronchitis</td>
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<td>- Mycetoma</td>
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<td>B. Necrosis of lung parenchyma</td>
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<td>- TBC</td>
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<tr>
<td>- Necrotizing bacterial pneumonia</td>
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<td>- Septic embolism</td>
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<td>C. Primary or metastatic lung cancer</td>
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<td>D. Vascular disorders</td>
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<td>- Chronic occlusion of the pulmonary artery: chronic thromboembolic disease, vasculitis</td>
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<td>- Aneurysm (Behçet disease and Hughes–Stovin syndrome) and pseudoneurysm (Rasmussen aneurysm) of the pulmonary artery</td>
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<tr>
<td>- Bronchial artery aneurysm</td>
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<tr>
<td>E. Iatrogenic or traumatic penetrating injuries</td>
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<td>- Malposition of the Swan–Ganz catheter (pulmonary artery pseudoneurysm)</td>
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<td>- Penetrating trauma</td>
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<td>F. Cryptogenic hemoptysis</td>
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<tr>
<td>2. Congenital disorders</td>
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<tr>
<td>- Sequestration / pseudosequestration</td>
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<tr>
<td>- Pulmonary arteriovenous malformation (Rendu-Osler syndrom)</td>
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Figure 2. Patient with pleuritic chest pain and LTH. TC (lung window) showing ground-glass opacities and centriflobular nodules in the right upper lobe due to the bleeding; a clot is filling a subsegmental bronchus (arrowheads).

Fig. 3: Fig. 2.
Figure 3. Patient with mycobacterium avium active infection who presents LTH. a) TC (lung window) performed 5 months before hemoptysis showing cavitating lesion with irregular walls in the left upper lobe. b) TC (lung window) the cavity is filled with blood indicating the site of bleeding. c) axial MIP showing visualization of pulmonary artery branches within the cavity a finding suspicious of pulmonary artery involvement in the bleeding.

Fig. 4: Fig. 3.
Figure 4. Patient with life-threatening hemoptysis. a) Image of consolidation and a surrounding ground-glass area in the posterior segment of the right upper lobe, secondary to the bleeding; These findings completely resolved in the follow-up CT  b) performed one month later.

Fig. 5: Fig. 4.
**Figure 5.** a-d. Diagrams illustrate the types of orthotopic bronchial arterial supply.  
**Type 1 a)** two bronchial arteries on the left and one bronchial artery on the right that present as an intercostobronchial trunk (ICBT) (40.6%).  
**Type 2 b)** one bronchial artery on the left and one ICBT on the right (21%).  
**Type 3 c)** two bronchial arteries on the left and two bronchial arteries on the right (one ICBT and one bronchial artery) (20%).  
**Type 4 d)** one bronchial artery on the left and two bronchial arteries on the right (one ICBT and one bronchial artery) (9.7%).

**Fig. 6:** Fig. 5.
**Figure 6 a)-e).** Patient with bilateral mycetomas. a) Chest radiograph showing significant loss of volume of the upper lobes with large cavities. Nodular images are observed within the cavities (arrows) corresponding to mycetomas. b) axial MIP shows hypertrophy of right (white arrows) and left bronchial arteries (black arrows) and the left and mycetoma (*). c) coronal MIP showing an ectopic bronchial artery from the right subclavian artery entering to the lung through the hilum.

d) Arteriography showing ectopic bronchial artery from the right subclavian artery (arrows). e) posterior coronal MIP reconstruction, showing hypertrophy of superior left intercostal arteries (arrows) associated with pleural thickening.

**Fig. 7:** Fig. 6.
**Figure 7.** Patient with cystic fibrosis and LTH. **a)** CT (lung window) bilateral widespread bronchiectasis. **b)** axial MIP showing multiple hypertrophied bronchial arteries (white arrows) The right intercostobronchial trunk presents an aneurysm (black arrow). Reactive lymph nodes (*) are also seen.

**Fig. 8:** Fig. 7.
**Figura 8.** Patient with tuberculosis sequel and necrotizing pneumonia in the right lower lobe. CT showing loss of volume of the right lung with and old calcified pleural collection (arrows). Hypertrophied intercostal artery is seen within the enlarged subpleural fat (arrowheads).

**Fig. 9:** Fig. 8.
Figure 9. Patient with lingular bronchiectasis, with history of previous (one year ago) bronchial arteries embolization. Now presents a new episode of life-threatening hemoptysis. a) CT (lung window) showing lingular bronchiectasis (arrowhead). b) -d) Images of MDCT angiography, b) axial section at subdiaphragmatic region showing tortuous left phrenic artery (arrows). Oblique coronal MIP c) and d) show the path of nonbronchial systemic artery from the celiac trunk (*) to the lingula (arrows). e) Angiography confirms the CT findings: a phrenic artery supplying the lingula.

Fig. 10: Fig. 9.
**Figure 10.** 26 years-old patient with unremarkable history, presenting with LTH. **a)** CT (lent window) shows right lower lobe consolidation, with surrounding ground-glass images. **b)**-**c)** images of MDCT angiography, **b)** axial image showing a vascular anomaly (arrow) in the right lower lobe adjacent to consolidation. **c)** oblique coronal MIP showing an anomalous vessel originating from abdominal aorta (black arrows) going to the right inferior lobe, findings suggestive of a sequestration **d)** volume rendering reconstruction showing the anomalous systemic abdominal vessel (white arrows).

**Fig. 11:** Fig. 10.
**Figure 11.** Patient with septic emboli who presents with LTH. **a)** TC (lung window) shows cavitated peripheral and central nodules in both lungs (arrows) consistent with septic emboli. **b)** MDCT angiography shows enhancing round vascular lesions with attenuation similar to that of central arteries, corresponding to bilateral mycotic pseudoaneurysms (arrows). **c, d)** MIP clearly depicted the saccular pseudoaneurysms arising from segmental branches of both pulmonary arteries (arrowheads).

**Fig. 12:** Fig. 11 a-d.
Figure 11 e,f. Patient with septic emboli who presents with LTH. e) In the non-selective right pulmonary artery angiography no pulmonary pseudoaneurysm were shown; f) segmental and subsegmental angiography was performed on the basis of the information provided by the MDCT, we show one of the pseudonaeurysm in the right upper lobe.

Fig. 13: Fig 11 e,f.
Conclusion

- The LTH is a serious clinical condition that requires prompt diagnosis and treatment.
- The treatment of choice is embolization.
- Bronchial circulation is the most frequent cause of LTH, but nonbronchial systemic arteries or pulmonary arteries can also cause bleeding, depending on the underlying pathology.
- MDCT angiography allows quick, accurate and noninvasive assessment of the cause, location and possible involved vessels. It is particularly useful for detecting ectopic bronchial arteries, nonbronchial systemic arteries and pulmonary artery pseudoaneurysms.
- The systematic use of MDCT angiography before embolization allows better planning of treatment, shortens angiographic time and helps reduce the rate of rebleeding.

References
