Transcatheter Embolization of Bronchial and Pulmonary Arteries: Indications, Techniques and Complications

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Learning objectives

- ANATOMY OF BRONCHIAL AND PULMONARY ARTERIES
- AETIOPATHOGENESIS OF HEMOPTYSIS
- TECNIQUE OF EMBOLIZATION
- POSSIBLE COMPLICATIONS AND TIPS & TRICKS TO AVOID THEM

DEFINITION of HEMOPTYSIS: *cough with issuing of blood*

Hemoptysis is defined as mild if lost less than 15-20 ml of blood in 24 hours, as intermediate if lost amount of blood between 15-20 and 200-300 ml in 24 hours and is defined as massive with loss of 300 to 600 ml of blood in 24 hours.

Massive Hemoptysis is cause of death (which occurs from asphyxiation rather than as a result of hypovolemia) in 50 - 85% of cases with conservative treatment and is the main indication for embolization procedures.

Surgical resection of the source of bleeding is the initial treatment of choice in cases of isolated abnormalities in patients with adequate pulmonary functional reserve.

In patients with chronic pulmonary disease and with reduced pulmonary reserve, and high surgical risk, is definitely indicated treatment with embolization.

Recent studies have demonstrated that can be given indication to treatment of embolization in case of moderate (=/> of 100ml/die in 1 week) or mild hemoptysis.

Background

**VASCULAR ANATOMY**

The lungs are the only organs receiving blood from both ventricles, the whole volume of right ventricle through the pulmonary arteries and a small portion of blood from left ventricle through the bronchial arteries.

**The bronchial arteries** most frequently arise from the thoracic aorta at the level of D3 - D8, in 80% between D5 - D6, and supply the trachea, bronchi, diaphragmatic and mediastinal pleura, the vagus nerve, the posterior mediastinum and the esophagus.
However several anatomical variations in the origin of these vessels have been described:


1. two bronchial arteries on the left and one on the right that arises as intercostal-bronchial trunk (40.6%)
2. one bronchial artery on the left and one intercostal-bronchial trunk on the right (21.3%)
3. two arteries on the left and two on the right, of which one as intercostal-bronchial trunk (20.6%)
4. one artery on the left and two on the right, of which one as intercostal-bronchial trunk (9.7%).

Fig. 1: Diagrams illustrate the 4 types of bronchial arterial supply


About 20% of bronchial arteries do not arise from descending thoracic aorta and about 10% arise from concavity or convexity of the aortic arch. Other anomalous origins may come from the subclavian artery, thyrocervical trunk, internal mammary artery, brachiocephalic trunk, pericardiophrenic arteries, superior intercostal artery, abdominal aorta and inferior phrenic arteries. Bronchial afferents have been described even by coronary arteries.

The bronchial arteries run along the bronchi, down to the bronchiolar level where they anastomose with the pulmonary circulation.

Fig. 2 on page 6 Fig. 3 on page 7

There is a very extensive anastomotic network between bronchial circle and other arterial systems in case of lung failure and disease or in course of pulmonary hypertension.
Special attention should be paid to the vascularity of the spinal cord. The anterior spinal artery sprays the front of the spinal cord, running in the ventral median sulcus. It arises from branches of the intracranial sections of vertebral arteries and receives afferents from anterior radiculomedullary branches of intercostal and lumbar arteries. There may be six to eight branches tributaries to anterior spinal artery and each of these has a characteristic course that resembles a hairpin loop.

The largest anterior medullary branch is the artery of Adamkiewicz, which has variable origin between D5 and L5 (most often between the level of D8 and L1). It's important to know that in about 5% of the population a right bronchial artery can supply or connect with the artery of Adamkiewicz. In addition, the superior right intercostal artery and the right bronchial artery may have a common trunk of origin from which it is possible the birth of a branch to the anterior spinal artery. Instead the origin of anterior spinal afferent branches from the left bronchial tree is extremely rare.

The **pulmonary arteries** originate from the bifurcation of the pulmonary trunk. The left divides into ascending branch (to the upper lobe) and descending branch (to the lingula and lower lobe). The right main pulmonary artery bifurcates into a small upper trunk (to the upper lobe) and a larger lower trunk (to middle and lower lobes).

The following sub-divisions of the pulmonary arteries reflect those of the segmental bronchi:

on the right there are 3 segmental branches to the upper lobe (apical, anterior and posterior), 1 (that immediately divides into a medial and a lateral branch) or 2 to the middle lobe and 5 to the inferior lobe (superior, medial basal, anterior basal, posterior basal, lateral basal).

On the left there are 2 segmental branches to the upper lobe (apical posterior and anterior) and 3 or 4 to the lower lobe (superior, anteromedial basal - or anterior basal and medial basal - and lateral basal). The lingular artery arise as first branch from the descending trunk and divides into a superior and an inferior branch.

**Fig. 4** on page 8

The nomenclature generally used in CT or MR Angiography is based on the distance of the vessel from the right ventricle: first-order branch, the main trunk; second-order branches, the main right and left arteries; third-order branches, the superior and inferior trunks and the "lobar" arteries; fourth-order branches, the segmental arteries; fifth-order branches, the subsegmental arteries that arise directly from segmental arteries; sixth-order branches, which arise directly from the first division of subsegmental.

**Fig. 5** on page 8
ETIOPATHOGENESIS

Hemoptysis by bronchial arteries: severe hemoptysis of bronchial origin is most frequently found in patients with chronic lung diseases and the most common etiology is represented by TUBERCULOsis associated with ASPERGILLOSIS. The conditions of BRONCHIECTASIS, SARCOIDOSIS and CYSTIC FIBROSIS are common cause of chronic bleeding.

The chronicity of the condition favors catheterization of the vessels and then embolization, due to the vascular hypertrophy.

Fig. 6 on page 10 Fig. 7 on page 10

Fig. 8 on page 11 Fig. 9 on page 12

In 30 to 50% of cases has also been demonstrated the partial or total liability of collateral non-bronchial systemic arteries in cases of massive hemoptysis.

Fig. 10 on page 13

Hemoptysis by pulmonary arteries: massive bleeding originating from the pulmonary circulation is more uncommon. It is generally secondary to pseudoaneurysms, in association with aspergillosis or cavitary tuberculosis (Rasmussen’s aneurysm) or lung abscess or pulmonary A-V fistulas and malformations (PAVF - PAVM).

Fig. 11 on page 14 Fig. 12 on page 15

Genetically determined forms: Hereditary Hemorrhagic Telangiectasia or Osler-Weber-Rendu Syndrome represents the most frequent cause of PAVMs and is of particular interest due to the therapeutic role of choice of transcatheter embolization. It consist of direct abnormal low pressure connections between a pulmonary artery and a pulmonary vein, therefore skipping the capillary circulation, possible causes of hypoxia and dyspnea, due to the shunt, cardiac failure, paradoxical embolism, bleeding.

Fig. 13 on page 16

In 35-38% of cases the lesions are multiple and bilateral in 30-40%, especially in the lower lobes (50-75%).
PAVMs are distinguished in "simple " (90% of cases), when one or more arteries however originate by a single segmental artery, and "complex" (10% of cases), when the arteries always originate from two or more segmental arteries. In about 5% of patients there is a diffuse form, characterized by small PAVMs arising at the level of each terminal branch, especially in the lower lobes.

Pulmonary artery aneurysms can be found in course of chronic pulmonary hypertension, in Behçet Syndrome, in Takayasu Arteritis, in Hughes-Stovin Syndrome (different form of Behçet S.) or in Marfan Syndrome.

Fig. 14 on page 17

Among the autoimmune forms responsible for bleeding, affecting terminal arterioles, Goodpasture's Syndrome, Wegener's Granulomatosis, Churg-Strauss Syndrome are to remember.

Images for this section:

Fig. 1: Diagrams illustrate the 4 types of bronchial arterial supply
Fig. 2: Course of bronchial arteries
Fig. 3: Distal anastomosis between bronchial and pulmonary arteries

Fig. 4
Fig. 5

Fig. 6: Hemoptysis: Chronic Inflammation (sarcoidosis)
Fig. 7: Hemoptysis: TBC
Fig. 8: Hemoptysis: Chronic Inflammation
Fig. 9: Hemoptysis: TBC
Fig. 10: AVF superior intercostal a.
Fig. 11: Respiratory insufficiency. Complex PAVM middle lobe
Fig. 12: Respiratory insufficiency. Complex PAVM middle lobe
Fig. 13: Paradoxical embolism. Rendu-Osler S. (Simple PAVM).
Fig. 14: Hemoptysis. Behçet Syndrome. Aneurysm of lateral-basal subsegmental branch of right pulmonary artery.
TECNIQUE

Bronchial arteries: the selective catheterization of bronchial arteries can be preceded by thoracic aortography (particularly in cases not subject to CT preliminary study). Thoracic aortography is necessary in case of failure to find selectively bronchial vessels and in researching non-bronchial vessels responsible or co-responsible for bleeding, particularly in case of hemoptysis recurrence in patients already undergone bronchial embolization, followed by selective catheterization. If systemic vascular contributions don't be shown it is opportune to perform selective pulmonary arteriography to the search of possible pseudoaneurismus or pulmonary FAV escaped the preliminary studies (CTangio - MRIangio).

Fig. 15 on page 33 Fig. 16 on page 34

Fig. 17 on page 35 Fig. 18 on page 36

- Femoral access, placing a long vascular sheat (50 - 60cm), 6 - 7 French of size.

- Wide choice of selective catheters (Mikaelson, Simmons 1, J curve, Sherped's Hook, Cobra, Headhunter 1, RC), 4 or 5 F.

- If the bleeding site is known occlusion may be confined to the afferent vessels (bronchial and not) to the target, otherwise embolization is recommended both sides.

- Always embolize the dominant vessel and then try to treat the largest possible number of afferent vessels to the area of bleeding, focus mainly on clinical data.

- Perform the embolization as distal as possible, because the only proximal occlusion of a vessel stimulates the development of distal collateral vessels and prevents the possibility of future retreatment.

- To proceed to safe embolization the catheter must be stable and non-occlusive to avoid the possibility of reflux or lack of progress of particles. If this is not possible is necessary to resort to the coaxial technique, using a microcatheter.
- The opportunity to embolize a bronchial artery with documented contribution to a spinal vessel is controversial and depends on the experience of the operator and the risk / benefit ratio. The use of particles with diameter > 250 μm reduces the possibility of medullary complications as elements of this diameter cannot pass into the spinal afferents.

It is however preferable superselective catheterism downstream of spinal connection, using a microcatheter.

- Absorbable material (Avitene, Gelfoam, Spongostan) is certainly safer, but offers risk of recurrent bleeding.

Fig. 19 on page 37

- Non-absorbable particles (PVA) or Microspheres offer most definitive and lasting success. Generally PVA particles with diameter > 250 μm (300-500 μm or 500-700 μm) are used. Beads are used also with greater diameters (700-900 μm) due to the perfectly smooth spherical morphology and deformability.

Fig. 20 on page 38 Fig. 21 on page 39

- Cyanoacrylates can be used successfully, but require a highly experience.

Fig. 22 on page 40

- You must instead avoid the ethanol and Gelfoam powder: they can cause distal embolization and therefore possible infarct lesions.
**Fig. 23:** Hemoptysis: bronchial angiodysplasia. Left bronchial artery. Spongostan + microcoil

**References:** C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY
Fig. 24: Hemoptysis: left lower lobectomy outcomes for bronchiectasis. AVF (bronchial a. - pulmonary a.). Left common trunk and left superior intercostal a. Cyanoacrilate

References: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY

Fig. 25: Hemoptysis: left lower lobectomy outcomes for bronchiectasis. AVF (bronchial a. - pulmonary a.). Right and left common trunk. 150-300 µm Beads.

References: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY
Fig. 26: Hemoptysis. TBC. AVF superior intercostal a. - pulmonary a. Particles (355-500 μm) + microcoil
References: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY

Fig. 27: Hemoptysis. TBC. R and L Common Bronchial Trunk. Right embolization with Cianoacrylate.
References: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY
Fig. 28: Recurrent hemoptysis. Left bronchial artery embolization outcomes in AVF. Left internal mammary a. - left inferior pulmonary v. AVF. Cyanoacrilate + coils.

References: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY

Pulmonary Arteries:

- Selective pulmonary angiography is the most accurate method in the evaluation of peripheral pulmonary circulation.
- Femoral or more rarely jugular approach: crossing right atrium, tricuspid valve, right ventricle and pulmonary valve, pulmonary trunk and finally pulmonary artery of interest are catheterized, by high flow pigtail or omniflush catheter (5, 6 or 7 F).

- Multiple techniques: premounted steerable guidewires on standard pigtail or preformed catheters with standard or curved torque control guidewires.

- Arteriography is usually performed by injecting 30 to 60 ml of contrast medium at a flow rate of 15 to 30 ml/sec, reducing it in case of pulmonary hypertension, with high-speed frame rate (> 4 frames/sec).

- Before proceeding to the stage of embolization, with femoral access, it is better to place a long vascular sheat, 7 - 8 F of size, preferably to the pulmonary trunk or pulmonary artery on the side of interest.

- The most commonly used catheters for the catheterization of the pulmonary branches are multipurpose catheters and Berenstein, 5 or 6 F size with inner lumen of .038", with floppy or Bentson guidewires or Terumo angled guidewires.

- The treatment of aneurysms and that of PAVMs is very similar, because the latter are in fact characterized by a dilated afferent segmental artery that supplies an aneurysmal sac with quick drain vein.

- The choice ranges from Coils to Detachable Balloons to Amplatzer Plugs.

- Often in malformations with small afferent arteries (diameter 3-5 mm) and distally located, 4 F hydrophilic catheters or even microcatheters must be used to place microcoils or Amplatzer Vascular Plugs 4 (latest generation, introduced in 4 F diagnostic catheters). In case of large vessels is easily possible to place a larger catheter (up to 8 F) to use detachable balloons or bigger Amplatzer Plugs (up to 22 mm). The use of standard coils provides to place 4, 5 or 6 F diagnostic catheters.

Fig. 29 on page 45 Fig. 30 on page 46

- Until the advent of Plugs, Detachable Balloons were the most commonly used system, due to the possibility to verify the effectiveness and the position before the final release, and to the guaranteed success. The limit of this system is the need to place a proximal vascular sheat, often of large caliber, in the vessel of interest.
The use of embolization coils often requires a high number of elements to achieve complete vessel occlusion. It begins by placing a pair of coils with a diameter greater than 2 mm compared to that of the vessel, followed by others with ever-decreasing diameter, to form a compact nest and obtain complete occlusion.

Vascular Plug can be placed without final release, and then repositioned. If the correct size (2 mm oversizing), the result is complete occlusion of the vessel. Compared to Detachable Balloons, Plugs offer advantage of not requiring proximal introducer and be adaptable to diagnostic catheters.

Fig. 31: Respiratory failure. Middle lobe complex PAVM. (coils + 2 Amplatzer Plugs)

References: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY
Fig. 32: Rendu-Osler Weber S. (simplex PAVM). Right cerebellar and pontine paradoxical embolism. Coils (MRI DWI, CT, Dynamic MR angiography, angiography).

References: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY

Fig. 33: Hemoptysis. Bechet S. Posterior basal subsegmentary branch of right pulmonary artery aneurism. Coils.

References: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY
COMPLICATIONS

Bronchial Embolization:

- The spinal cord infarction and transverse myelitis are the most feared complications during bronchial embolization, even though the literature shows that in fact this is a potential problem than real.

TIPS:

- Getting proper bronchial arteriography prior to embolization procedure, which would identify any connections with the anterior spinal artery.
- Perform superselective catheterism down the possible spinal connection with use of microcatheter.
- Using particles with diameter > 200 to 250 µm or microspheres with a diameter > 300 µm.
- Some authors (Lois et al 1988, Doppman et al 1986) recommend the use of provocative tests, with intraarterial Amobarbital or Lidocaine that produce temporary symptoms similar to spinal cord ischemia.

- The possibility of having problems with bronchial infarct is extremely rare. The literature reports only two cases (one fatal), both using liquid sclerosing agents.

- Have been reported cases of broncho-esophageal fistula with the use of very small particles and concomitant bronchial and oesophageal ischemia.

- It’s common event onset of chest pain and dysphagia from 2 to 7 days after embolization, usually with spontaneous resolution.
Fig. 34: Single bronchial artery

References: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY
Fig. 35: Embolization: extrabronchial connections opening but not hairpin loop.
100-300 µm beads

References: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY
**Fig. 36**: MR at 24 hours: normal

**References**: C. Ballarati; Special Procedures, Dept of Radiology, Como, ITALY
Pulmonary Embolization:

- Possible complication of PAVMs embolization is paradoxical embolism, and that the migration of the used elements in the venous territory of the fistula and then into the systemic circulation.
TIPS: perform preliminary assessment of the precise diameter of the target vessel and use balloons, coils or plugs sufficiently oversized.

- During the maneuvers it is possible accidental introduction of air into the catheter that could reach the right coronary artery, whose ostium, in supine patient, is located in antigravitary position. It presents with chest pain, bradycardia, extrasystoles, usually without leaving electrocardiographic sequelae, although the severity of the event is proportional to the amount of migrated air bubbles.

TIPS: avoid accidental introduction of air, for example constantly holding the bottom of the catheter immersed in a saline drip during maneuvers.

- In the course of treatment of pseudoaneurysms should be considered the possibility of rupture of the same, typically related to the fragility of the structure, during the maneuvers.

TIPS: avoid handling the sac, but simply place the catheter into the afferent vessel, occluding it, possibly with previous filling of the aneurysmal sac with coils, however released in the afferent vessel and left carried by the arterial flow.

- In about 20% of cases there may be a pleuritic reaction, 48 to 72 hours later or even delayed to 4-5 days after the procedure, characterized by fever and pleuritic pain, probably related to pulmonary infarction localized at the site of embolization, however quickly resolved with antibiotics and symptomatic therapy.

Images for this section:
Fig. 15: CT Angio planning: shortens the catheterization
Fig. 16: Extrabronchial vessels arteriography
Fig. 17: Thoracic arteriography
Fig. 18: Pulmonary arteriography
- GELFOAM: absorbable gelatin sponge
- AVITENE: microfibrillar hemostatic collagen
- SPONGOSTAN: hemostatic absorbable gelatin sponge

they are reabsorbed in few days

Fig. 19
Fig. 20: PVA (Polivinyl Alcohol): Contour Emboli, Ivalon. Water-soluble synthetic resin, biocompatible, non resorbable
Fig. 21: Acrilic Microspheres (Beads): Contour SE, Embosphere, Embogold, Embozene, Bead Block.
Fig. 22: Cyanoacrylic glue
Fig. 23: Hemoptysis: bronchial angiodysplasia. Left bronchial artery. Spongostan + microcoil
**Fig. 24:** Hemoptysis: left lower lobectomy outcomes for bronchiectasis. AVF (bronchial a. - pulmonary a.). Left common trunk and left superior intercostal a. Cyanoacrilate

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Fig. 30: Amplatzer Vascular Plugs
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Fig. 34: Single bronchial artery
Fig. 35: Embolization: extrabronchial connections opening but not hairpin loop. 100-300 µm beads
Fig. 36: MR at 24 hours: normal
Fig. 37: MR at 5 days: ischemia
**Conclusion**

Bronchial embolization can be considered a very effective technique in the immediate control of hemoptysis by inflammatory causes.

Literature shows a success rate of long-term control of hemoptysis between 70 - 80%, as related to the natural progression of the considered disease.

Repeated embolizations are often required, especially in young patients with a longer prognosis.

Recurrent hemoptysis are more frequent in patients with advanced pleural disease, moreover less controllable by the presence of frequent non-bronchial systemic vascular contributions.

In contrast the best success is achieved in cases of cystic fibrosis, where the palliative treatment is extremely important in order to lead the patient to transplantation.

The use of appropriate techniques significantly reduces the possibility of complications.

Embolization of PAVMs and aneurysms of the pulmonary artery is the treatment of choice, with success of definitive occlusion in 90% of cases, with a low incidence of major complications (paradoxical embolism, air embolism), in the order of 5%.

It's still important to set a long-term X-ray and CT follow-up to ensure persistence of occlusion of the treated lesions and monitor the growth or the onset of other PAVMs.

The treatment of pseudoaneurysms in most cases is able to stop the bleeding even if the data in the literature shows that mortality remains high for the compromised general functions and the concomitant weakening relative to the underlying disease.
Personal Information

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