Bronchial artery embolization in the management of hemoptysis

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Learning objectives

• Describe the pathophysiology of hemoptysis and the relevant anatomy of bronchial and non-bronchial systemic arteries
• Evaluate the indications of bronchial artery embolization (BAE) as well the diagnostic work-up prior to the procedure.
• Describe the imaging findings, approaches, techniques, outcomes and complications of bronchial artery embolization (BAE).
Background

The expectoration of blood from the respiratory tract is defined as hemoptysis. The classification of the severity of hemoptysis in literature demonstrates an element of subjectivity as there are many factors which can contribute to the impact of the symptom e.g. volume of bleeding, duration of presentation and the impact on clinical state of the patient.

With the aforementioned factors in mind, it can been classified into different grades of severity; mild, moderate and severe/massive:

- **Mild hemoptysis** - <100ml per day
- **Moderate hemoptysis** - 100-300ml per day
- **Severe/massive hemoptysis** - >300ml/day or any volume causing respiratory failure or hypotension (<90mmHg)[1][2]

The vast majority of cases of hemoptysis often arise from the bronchial vasculature (systemic circulation) due to the presence of inflammatory lung pathologies exacerbating hypoxia. The reduced oxygen saturations result in vasoconstriction of pulmonary arterioles therefore causing a decline in pulmonary arterial perfusion. Compensatory hypertrophy, neovascularisation and anastomoses of bronchial arteries with pulmonary circulation occurs due to prolonged inflammatory processes causing the release of angiogenic factors [3]. Although this collateral flow aims to increase gas exchange, the bronchial arteries are often fragile and prone to rupture. This is further propagated by the high pressure systemic circulation and inflammatory/infective etiologies that may initially cause the hemoptysis [2].

The commonest cause of significant hemoptysis worldwide is active pulmonary tuberculosis (TB) and post-infective sequelae of TB e.g. bronchiectasis and fibrosis [4][5]. Other non-cardiac causes include: bronchial carcinoma, aspergilloma, granulomatosis with polyangitis, pneumoconiosis, SLE, Behcet's, COPD, congenital heart disease, cryptogenic hemoptysis, sarcoidosis and cystic fibrosis; the latter two being prominent in the western world[6]. A key distinction is that bronchial vessel hypertrophy is less common in malignancy, compared to post-infective or inflammatory causes. It is also important to consider cardiogenic causes of hemoptysis e.g. left heart failure, pulmonary embolism, aorto-pulmonary aneurysm and bleeding diathesis[2].

First introduced in 1974 by Remy et al.[7], bronchial artery embolization (BAE) has evolved as an effective and mainstay treatment modality for hemoptysis due to its minimally invasive nature. Improvements in techniques have allowed for its widespread implementation. BAE is the recommended procedure in massive hemoptysis after hemodynamic stabilisation of a patient. Although surgery is preferred for localised
disease and appropriate surgical candidates, BAE can be implemented to reduce the rates of intraoperative bleeding. BAE also has elective applications for poor surgical candidates with extensive, bilateral pulmonary pathology.

It is essential for interventional radiologists to be aware of the lung blood supply to effectively manage hemoptysis. The two key considerations include: bronchial arteries and non-bronchial systemic arteries.

**Bronchial Arteries:**

Bronchial arteries supply the bronchi, visceral pleura, oesophagus, vasa vasorum of aorta and pulmonary artery as well as regional lymphatics. Their course characteristically is along the branching of the bronchi. Orthotopic bronchial arteries are present in 65-70% of the population and branch off the descending thoracic aorta at the T5/T6 level. Four classic configurations are described by Cauldwell et al. based on autopsy data from 150 cadavers[8].

The commonest vascular structure encountered in angiography is the right intercostobronchial trunk which divides into: a) bronchial branch (running parallel to the right bronchus branching point) and b) intercostal branch which ascends and travels in the lower border of the rib. The common bronchial artery is also commonly seen which can supply both lungs via the left and right bronchial arteries which branch off it. The left lung often has a separate left bronchial artery.

Ectopic bronchial arteries have the same parallel course along the bronchial tree as orthotopic arteries, however arise from different locations of the descending thoracic aorta and may even branch off locations such as: internal mammary artery, aortic arch, thyrocervical trunk, costocervical trunk, subclavian artery, inferior phrenic artery or abdominal aorta.

There are some important communications of bronchial arteries with systemic vessels e.g. the right intercostobronchial trunk can communicate with anterior medullary arteries which supply the spinal cord via the anterior spinal artery. The artery of Adamkiewicz (great anterior medullary artery) is the most prominent (T9-T12). Embolization of these communicating vessels can exacerbate cord ischaemia or transverse myelitis, which is why superselective embolization distal to the origin of the vessel needs to be employed[1][2].

**Non-bronchial Systemic Arteries (NBSA):**
These vessels have a non-parallel course to the bronchial tree and enter the lungs via a transpleural route or through the pulmonary ligament. They must be differentiated from bronchial arteries as they often pose an angiographic dilemma due to collateral formation. Early hemoptysis recurrence despite BAE which was deemed to be successful, suggests a possibility of NBSA. NBSA are often found in chronic inflammatory processes and can arise from several locations e.g. intercostal, subclavian, internal mammary, costocervical, or phrenic arteries[9].
Findings and procedure details

**Diagnostic Evaluation: Pre-procedure**

Prior to the treatment of hemoptysis by BAE, a full clinical history and examination should be performed to formulate a list of differential diagnoses and potential causes for the bleeding. As discussed previously, hemodynamically instability warrants urgent resuscitation of the patient and close monitoring of vital signs prior to any intervention.

Chest radiography is recommended by the American College of Radiology (ACR) for all new cases of hemoptysis as a form of initial evaluation[10]. A chest radiograph can be performed quickly in the context of an acute emergency and is effective at localizing the cause of the hemoptysis to a particular lung zone. Although, radiographs have shown to be diagnostic in 50% of cases[11], analysis can be difficult in the case of bilateral lung disease or massive hemoptysis causing increased density in both lungs.

Rigid or fibreoptic bronchoscopy can both be used as an evaluation tool, the former requiring general anaesthesia and being less portable than the latter. Evidence suggests that bronchoscopy can often fail at locating the cause of hemoptysis in 50% of cases[12].

The latest advancements in iterative technologies has led to the use of multidetector computed tomography (MDCT) to identify the causative mechanism of hemoptysis as well as for haemorrhage lateralization. Advantages of this include: fast acquisition times, reduced motion artefacts and 3D multiplanar reconstructions. Furthermore, the use of CT with contrast enhancement allows for the evaluation of parenchymal and vascular etiologies of hemoptysis. CT bronchial angiography can also highlight hypertrophic vessels and can accurately illustrate a thoracic vascular network, thereby guiding intervention[10][13].

**Bronchial Artery Embolization (BAE) Procedural Technique**

Digital subtraction angiography (DSA) is performed prior to BAE to visualise bronchial and non-bronchial systemic vessels. The commonest route of arterial access is the transfemoral approach using a 5 or 6 French sheath, however a transbrachial route may be considered in cases of increased tortuosity of the aorta and/or complicated NBSAs[5][14]. The latter approach is associated with higher rates of complications.

A flush thoracic aortogram is performed after acquiring vascular sheath access into the femoral artery, with an aim to locate abnormal bronchial vessels and NBSAs arising from
the descending thoracic aorta[15]. Approximately 30mL of dilute iodinated contrast agent is injected during a breath hold at a rate of 18mL/s and DSA images are acquired in AP mode of projection. CT bronchial angiography can be performed as a substitute to an aortogram due to the latter having drawbacks regarding inadequate filling of subclavian arteries (SCA), which can require separate SCA runs and increased exposure of contrast to head and neck vessels.

Catheterisation is subsequently performed using a superselective approach using microcatheters (2.7 French). Prior to their use, renal double curve catheters are used to 'hook' bronchial arteries, followed by a contrast run. A microcatheter is then advanced through the primary catheter. This has the benefit of improving hemoptysis control by embolizing distal, small vessels and avoiding the risk of embolizing anterior spinal arteries, thereby reducing complications[1][2].

**Abnormal bronchial arteries** can be determined by features suggesting:

- Hypertrophy (>3mm diameter)
- Tortuosity
- Arterial or venous shunting into pulmonary vasculature
- Abnormal vascular blush suggesting neovascularisation or hypervascularity
- Contrast extravasation
- Pseudoaneurysm
- Any NBSA in diseased lung segment
Fig. 1: Hypertrophied intercostobronchial trunk with evidence of vascular and parenchymal blushing on digital subtraction angiography

References: Department of Radiology, Queens Hospital, Barking Havering and Redbridge University Hospitals NHS Trust, London, United Kingdom
Fig. 2: Right bronchial artery arising from the right subclavian artery on digital subtraction angiography. Several anatomical variations and branching patterns of bronchial arteries exist in literature

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**Fig. 3**: Pre-embolization digital subtraction angiography demonstrating a tortuous right bronchial artery arising from the right internal mammary artery

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Fig. 4: A patient presenting with hemoptysis due to bronchiectasis affecting the lungs bilaterally. A) Right and B) Left bronchial arteries are hypertrophied and tortuous as depicted on this digital subtraction angiograph.

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When choosing an embolizing agent, several factors need to be considered e.g. size, effortlessness of delivery, durability of the agent and risk of recanalization.

Polyvinyl alcohol (PVA) is the commonest embolization agent used in current practice due to its non-absorbable properties which facilitate permanent occlusion, unlike gelatin sponge which provides temporary, proximal embolization and increased risk of recanalization. Common PVA particle sizes utilised in BAE are in the range of 300-500µm. Smaller sizes can result in pulmonary infarction and bronchial necrosis as a result of infiltration through the bronchopulmonary anastomoses. However, PVA particles are at risk of aggregating within microcatheters, causing some cases of unwanted proximal occlusion.

Microspheres, with their spherical and uniform shape, have a lower risk of clumping and have demonstrated clinically successful outcomes in the short-term[15].

Liquid embolizing agents such as n-butyl-2-cyanoacrylate (NBCA) have been reported to be effective in cases of bronchiectasis for the control of hemoptysis. These require more expertise from the operating interventional radiologist, increasing risks of complications e.g. non-target embolization[16]. Metallic microcoils are also used in the control of hemoptysis in BAE, albeit less frequently in recent times. These achieve proximal embolization which limits chances of further interventions in the event of hemoptysis.
recurrence. Microcoils are now reserved for the treatment of pseudoaneurysms, NBSAs or arteriovenous malformations[2].

**Fig. 6:** A) Pre-embolization angiography illustrating a hypertrophied, tortuous, right intercostobronchial artery with perivascular and parenchymal blushing. B) Post-Embolisation angiography showing absence of contrast flow.

**References:** Department of Radiology, Queens Hospital, Barking Havering and Redbridge University Hospitals NHS Trust, London, United Kingdom

**Fig. 7:** Patient with an occlusion of the aorta present below the origin of the renal arteries. A) Right bronchial angiography indicating bronchial artery embolization being performed through right brachial artery access as a result of technical difficulties. B) Occlusion of aorta below renal artery origins

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Fig. 8: This patient presented with hemoptysis and hemothorax. A) Pre-embolization angiography demonstrated the cause to be a right internal mammary artery to pulmonary artery fistula. B) The patient was subsequently treated with coil embolization.

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Fig. 9: Digital subtraction angiogram depicting a fistula of the internal mammary artery (IMA) and pulmonary artery (PA). This was subsequently treated with coil embolization of the IMA.

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Outcomes

Overall, BAE is an effective management technique with success rates ranging from 70-99% in terms of cessation/substantial decrease of hemoptysis[1]. However, recurrence probability increases with time and has been reported to be as high as 57% in some studies[17].
Recurrences occurring in the first 3 months are often due to failure of complete embolization as a result of: NBSA, ectopic vessels or simply a large proportion of hypertrophied vessels. Causes of late occurrences (>3 months) are usually as a result of progression of primary conditions and are attributable to the recanalization of treated vessels or development of new NBSA. Conditions most associated with rebleeding and recurrence include cavitatory aspergillomas, multi-drug resistant tuberculosis and bronchogenic carcinoma[18][19]. BAE is symptomatically effective in controlling recurrences but does not treat the underlying etiology of rebleeding which is why it is regarded as a palliative method. Patients should be considered for definitive surgical treatment wherever possible.

**Fig. 10:** This case depicts a hypertrophied, abnormal, tortuous intercostal vessel. It is sometimes necessary to embolize non-bronchial systemic arteries like these in cases of reoccurrence of persistent hemoptysis after bronchial artery embolization. In this particular case, the enlarged intercostal vessel was embolized.

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**Complications**

**Common:**
• **Chest pain** - commonest presentation (35%) but usually self-limiting. Occurs as a result of non-target embolization of systemic branches, intercostal arteries or bronchial artery dissection[1][2].

• **Dysphagia** - 2\textsuperscript{nd} most common presentation (18%). Self-limiting esophageal non-target embolization.

• **Post-embolization syndrome** - fever, pain and leukocytosis (30%) [5]

Other:

• **Spinal Ischemia** - occurs in 1.4-6.5% of cases. Unintentional embolization of spinal arteries causing transient paraparesis or paraplegia, which may progress to permanent damage[20]. Superselective microcatheter embolization has reduced incidence of spinal ischaemia, however some studies contraindicate embolization in the presence of the anterior spinal artery on an angiogram[17].
Fig. 11: In certain situations, the anterior spinal artery can arise from the bronchial artery as demonstrated in this angiogram. This significantly complicates bronchial artery embolization due to a risk of paraparesis or paraplegia (the most serious complication of the procedure) due to interference of this vessel. Embolization was not performed in this patient with respect to the factors mentioned.

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- **Vascular damage** - technical errors in causing perforation, dissection or vasospasm
- Pseudoaneurysms
- Hypersensitivity to contrast
- Contrast-induced nephropathy
- Inguinal Haematomas

Rare:

- Cortical blindness
- Bronchial necrosis/stenosis
- Bronchoesophageal fistula
- Ischaemic colitis
- Pulmonary infarction
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Fig. 5: Bronchial artery angiogram demonstrating a pseudoaneurysm as a cause of bleeding. Pseudoaneurysm formation is an indication for coil embolisation.

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Conclusion

• Hypertrophy of bronchial vessels due to lung parenchymal abnormalities is the main cause of acute, life-threatening hemoptysis.

• Bronchial artery embolization (BAE) is a well-known, established treatment and has an excellent technical success rates due to improvements in embolization agents, materials and techniques.

• Recurrence of bleeding is dependent on primary lung disease etiology, recanalization of primary embolization and development of collateral circulations which can be managed palliatively with BAE.

• Complication rates are in decline with improvements to the technique however: chest pain, dysphagia and post-embolization syndrome are common.

• It is essential for interventional radiologists to be aware of the bronchial and non-bronchial vascular anatomy to achieve successful outcomes.
References


