Review Article

Bronchial Artery Embolization for Life-threatening Hemoptysis: Preprocedural Imaging, Technical Considerations, and Management of Complications

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Life-threatening hemoptysis is one of the most challenging conditions of all respiratory emergencies, and requires prompt and proper treatment. With the advancement of catheter technology, efficacy of bronchial artery embolization (BAE) for hemoptysis has been well established. However, in some cases, recurrent hemoptysis may occur during a short period of time after BAE due to blood supply via missed bronchial arteries or nonbronchial systemic arteries. Therefore, knowledge of anatomical variation of bronchial arteries and nonbronchial arterial supply contributing to hemoptysis is essential to achieve excellent long-term as well as short-term results. Additionally, interventional radiologists should be familiar with proper selection of catheters and embolic materials to increase the technical success rate and to reduce the procedure-related complications. In this article, we illustrate angiographic and computed tomographic anatomy of the bronchial and nonbronchial arterial supply, technical aspects, results, and complications of BAE. We also discuss the risk factors influencing recurrent hemoptysis after BAE.

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Introduction

Hemoptysis, when massive and untreated, has a high mortality rate (1). Bronchial artery embolization (BAE) has been established as an effective treatment for massive hemoptysis (2-13). Late-phase recurrence is inevitable in some instances, because this procedure does not address the underlying disease. On the other hand, early recurrence, which is often caused by technical failure and/or missed bronchial or nonbronchial systemic arteries (8, 9, 14), may be avoidable with some technical consideration and anatomical knowledge. In this article, we describe underlying diseases of hemoptysis, anatomy of bronchial artery and nonbronchial systemic arteries that can be a source of hemoptysis, role of preprocedural CT, and techniques and complications of BAE. Knowledge of them is essential for successful BAE.

Anatomy of bronchial artery

The bronchial arteries (BAs) vary considerably in their number and site of origin. According to previous literatures, the number of BAs on each side is usually single or two. However, in some cases, three or more BAs can be seen on each side (12, 15, 16, 17). Right BAs often originate from the intercostobronchial trunks, while the left BAs rarely originate from them. Right and left bronchial arteries originate from the aorta as a common trunk at times (12, 17). Most of left BAs originate directly from the descending aorta or as the common trunk (Figure 1a). Takahashi et al. mentioned the relationships between origin site and intrapulmonary distribution of BAs. According to their report, right BAs originating from the intercostobronchial or subclavian arteries usually distributed to right upper lung, while right BAs originating directly from the aorta or as a common trunk usually distributed to right lower lung. Additionally, BAs originating from the aortic arch usually distrib-

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Figure 1. Diagrams illustrate origin sites of bronchial arteries
a. Common origin sites b. Uncommon origin sites

Figure 2. Common origin sites of the bronchial arteries (Two right BAs and two left BAs). All BAs, which were located between the T5-6 levels, were successfully catheterized with a shepherd's hook type catheter.

a. Arteriogram of the right intercostobronchial trunk, arising from right lateral aspect of the descending aorta, shows neovascularization in right upper lung. b. Arteriogram of the common bronchial trunk, arising from left anterolateral aspect of the descending aorta, shows neovascularization in both lungs. c. Left BA, originating from the descending aorta, shows neovascularization and an aneurysm (arrow) in left upper lung.

Figure 3. Uncommon origin sites of the bronchial arteries
a. The common bronchial trunk, which originates from the aortic arch, is successfully catheterized with a cobra type catheter. b. Right BA originates from right internal mammary artery.

uted to right lower or left upper lung (17).

BAs and the intercostobronchial trunks arise most commonly from the descending thoracic aorta between the level of the T5 and T6 vertebrae (Figure 1a, 2) (15, 18, 19). Twenty to thirty percent of BAs originate outside the area between the T5 and T6 vertebrae (15, 20). Anomalous origin sites of BAs include the concave surface of aortic arch, abdominal aorta, bilateral subclavian arteries and their branches (e.g. internal mammary artery, thyrocervical trunk, costocervical trunk etc.) (Figure 1b, 3) (15, 17, 21). Among anomalous origin sites, the concave surface aortic arch is most common (21).

Nonbronchial systemic arterial supply

Various nonbronchial systemic arteries (NSAs), which develop as collateral vessels in the presence of inflammatory process, can be a source of hemoptysis. NSAs arise commonly from the intercostal...
Techniques of BAE

Methods of BAs search and catheter selection

The search for BAs is usually begun at the T5 to T6 level. The air-filled left main stem bronchus serves as a convenient fluoroscopic landmark for general location of BA origin. The catheter tip is initially directed right posteromedially to medially when one is searching for the intercostobronchial trunk, and medially to anteriorly when one is searching for the right BAs originating directly from the aorta. An anterior direction is used for left bronchial artery catheterization. Descending thoracic aortogram may be useful in the detection of origin sites of BAs and/or nonbronchial systemic arteries responsible for hemoptysis (29). We usually begin with a shepherd’s hook type catheter for catheterization of the BA, because it is easy to control the direction of catheter tip in the descending aorta. However, such catheter may fail to adequately probe the aortic wall when the descending thoracic aorta is dilated and/or tortuous, or if the BA originates from the aortic arch. In such circumstances, a cobra type catheter can be used successfully. A microcatheter is often necessary to stabilize catheter tip in adequate position or to catheterize beyond orifices of radicular branches.

Embolic materials

Gelatin sponge particles are most commonly used in Japan, because it is inexpensive and easy to handle. However, recanalization due to absorption may cause early recurrence of hemoptysis. Polyvinyl alcohol particles are commonly used worldwide. However, smaller particles may pass through the bronchopulmonary anastomoses (72-325μm in diameter) (30), and may cause pulmonary infarction or systemic embolization. Generally, size of particles used for BAE is 350-500μm in diameter. Collateral vessels may develop immediately after proximal embolization using coils, thus causing early recurrence of hemoptysis. Additionally, repeat BAE is difficult in such cases (31). Hence, use of metallic coils should be limited to cases of BA aneurysms or iatrogenic rupture of BA induced by angiographic procedures. Absolute ethanol may cause tissue necrosis (32). Glue (isobutyl-2-cyanacrylate, n-butyl-cyanoacrylate) may preclude repeat embolization. Therefore those liquid materials are not generally used for BAE.

Role of preprocedural CT

CT plays important roles in evaluation of patients with hemoptysis. In most cases, the bleeding site can be localized at CT (Figure 6) (33). Bronchoscopic examination is also efficacious in assessing patients with hemoptysis as a complementary tool. However, localization of the bleeding site with this modality is difficult in patients with massive hemoptysis because of excessive blood in the bronchi. Diagnosing the underlying disease responsible for hemoptysis is essential to decide indication for BAE. Bronchiectasis, inflammatory lesions (e.g. tuberculosis, aspergillosis) (Figure 7), bronchogenic
carcinoma, vascular lesions (e.g. pulmonary arteriovenous fistula, aneurysm) etc. can readily be diagnosed at CT. On contrast-enhanced CT, enlarged bronchial and nonbronchial systemic arteries are often detectable in mediastinum or extrapleural fat (23, 34). These arteries may more clearly be depicted on 3D-CT angiography (Figure 8).

**Figure 6.** Role of CT - localizing the site of bleeding. A 50-year-old male with idiopathic hemoptysis. 

- **a.** CT clearly shows consolidation and ground glass opacity suggesting hemorrhage in the right upper lobe. 
- **b.** Right bronchial arteriogram, which was performed based on the CT findings, shows neovascularization in the right upper lobe.

**Figure 7.** A 71-year-old female with aspergillosis - good indication for BAE

- **a.** CT shows a fungus ball and surrounding opacities in the right lower lobe. 
- **b, c.** Selective arteriograms of right bronchial arteries show neovascularization in the right lower lobe. Embolization was done via these arteries.

**Figure 8.** A 72-year-old male with old pulmonary tuberculosis - good indication for BAE

- **a.** CT shows dilated bronchial arteries (arrows) through the mediastinum. 
- **b.** 3D-CT arteriogram shows orifices of bilateral bronchial arteries more clearly. 
- **c.** Selective arteriogram of right bronchial artery, which was readily catheterized based on CT findings, shows neovascularization in right lung.
Indication for BAE

Classically massive hemoptyisis, which is defined as 300 to 600ml per 24 hour period, was considered to be indication for BAE. However, the cause of death in patients with hemoptyisis is usually asphyxiation, and smaller amount of hemoptyisis can be life-threatening in patients with poor respiratory reserve. It is often difficult to exactly evaluate or forecast the amount of hemoptyisis. Hence, amount of hemoptyisis cannot be the absolute criterion for performing BAE although it is one of the factors influencing decision of indication (1, 19). Massive hemoptyisis results from various causes, and recurrence rate after BAE is influenced by etiologies of hemoptyisis. Therefore, etiology of hemoptyisis should be evaluated carefully to determine indication for BAE. Inflammatory lesions (e.g. tuberculosis, chronic bronchitis, aspergillosis, etc.) and bronchiectasis are good indication for BAE (Figure 7, 8). There is a group classified as having idiopathic hemoptyisis (cryptogenic hemoptyisis) in which chest roentogenography, bronchoscopy, CT, or clinical findings fail to reveal underlying disease. In our experiences, this group is also good indication for BAE. On the other hand, Adelman et al. reported that most patients with cryptogenic hemoptyisis were able to be controlled conservatively (35). Hence, in patients with this condition, indication for BAE should be considered carefully. Hemoptyisis related to neoplasms is not good indication for BAE. Hayakawa et al reported that hemoptyisis recurred within 1 month of BAE in 42% of the patients with neoplasms. In patients with chronic obstruction of pulmonary artery (e.g. Takayasu arteritis, primary pulmonary hypertension, peripheral pulmonary stenosis etc), BA may enlarge to serve as a collateral vessel, thus resulting in a source of hemoptyisis (36) (Figure 9). In such circumstances, indication for BAE should be considered carefully because BAE may induce pulmonary infarction and/or hypoxemia.

Patients with a ruptured thoracic aortic aneurysm may present with hemoptyisis (37)(Figure 10). In cases of large thoracic aortic

Figure 9. Primary pulmonary hypertension - unappropriate case for BAE
A 20-year-old male with primary pulmonary hypertension (PPH) presented with sudden onset of hemoptyisis.

a. Contrast-enhanced CT shows enlargement of the main pulmonary artery. b, c. CT images show well-defined ground glass opacity representing hemorrhage in left upper lobe. Additionally, ill-defined centrilobular opacities representing mosaic perfusion and/or hemorrhage are also seen in bilateral lungs. BAE was not done because the patient was suspected of having PPH. Generally, PPH is not a good indication for BAE because BAE may cause pulmonary infarction and/or hypoxemia.

Figure 10. Rupture of thoracic aortic aneurysm - unappropriate case for BAE
An 82-year-old male with aortic arch aneurysm presented with sudden onset of massive hemoptyisis.

a. CT images show consolidation adjacent to the aortic arch. Initially, hemoptyisis related to pneumonia or lung cancer was suspected, and BAE was attempted. b. Preliminary aortogram before BAE unexpectedly show a pseudoaneurysm arising from the aortic arch. c. Aortogram after endovascular stent-grafting shows complete exclusion of the pseudoaneurysm.
aneurysms, hemothysis related to a ruptured aneurysm can readily be diagnosed. However, in cases of small ruptured aneurysms, consolidation adjacent the aorta may mimic inflammatory lesions on chest radiograph and/or CT. The time delay of initial diagnosis and proper treatment may result in fatal outcomes. Therefore, whenever pulmonary hemorrhage is seen adjacent to the aorta, possibility of aortic rupture should be considered. Contrast-enhanced CT with multi-planer reconstruction is useful for the diagnosis of such conditions.

Rebleeding after BAE

Bronchial artery embolization has been shown to be a very effective technique for the immediate control of hemothysis due to inflammatory origin. Initial successful rates for BAE have been reported to be about 80 to 90%. However, long-term success rate of BAE is variable, being reported to be 52-80% (4, 6, 8, 9, 10, 11). Late-phase rebleeding may be caused by recanalization of previously embolized vessels, revascularization of the collateral circulation, or progression of basic lung disease (Figure 11). Recurrence rates may be influenced by etiologies of hemothysis, controllability of underlying disease, or number of collateral arteries (4, 6, 8, 13, 14, 28). Generally, aspergillosis-related hemothysis is difficult to control with BAE alone because medical control of aspergillosis is often difficult or impossible. Most of such conditions may require subsequent surgical intervention (12).

Complications

Several complications of BAE have been reported in the literature. Chest pain is the most common complication of BAE, but usually transient. Dysphagia occurs secondary to esophageal ischemia, and often regresses spontaneously (11,13, 38). Intimal injury of the vessels may induce occlusion of the BA, thus making subsequent BAE difficult or impossible. Mediastinal hematoma, although usually self-limiting, may develop secondary to iatrogenic BA rupture (Figure 12).

Spinal cord ischemia is the most disastrous complication due to the inadvertent occlusion of the artery of Adamkiewicz. Prevalence of spinal cord ischemia is reported to be 0-5.4% (4, 5, 8, 9, 11). Visualization of anterior spinal artery is absolute contraindication to embolization. However, interventional radiologists should keep in mind that embolization via the intercostal arteries or the intercostobronchial trunk can cause spinal cord ischemia even if the artery of Adamkiewicz is not depicted on angiograms (Figure 13). Other rare complications include bronchial and aortic necrosis, bronchoesophageal fistula, and non-target organ ischemia (13, 39).

Figure 11. Recurrent bleeding after BAE. An 88-year-old female with hemothysis due to old tuberculosis and chronic airway infection. Four sessions of BAE were performed for recurrent bleeding during 29 months. a, b. Arteriograms of the common trunk of bilateral bronchial arteries (a) and right bronchial artery (b), obtained before initial embolization, show marked neovascularization in both upper lobes. Immediate cessation was achieved after initial embolization. However, in this case, hemothysis repeatedly occurred, and the patient underwent four sessions of embolization during the follow-up period of 29 months. c, d. Arteriograms of right BA (c) and left internal mammary artery (d) obtained before fourth embolization show marked neovascularization again. In this case, chronic airway infection was medically uncontrolled, and this may have been the main cause for recurrent bleeding.
Figure 12. Complications - rupture of the bronchial artery. A 60-year-old male, with a history of lung cancer treated with surgery and irradiation, presented with hemoptysis. 
a. Left bronchial arteriogram shows neovascularization in left upper lung. b. Left bronchial arteriogram shows extravasation of contrast media indicating vascular injury caused by manipulation of a guidewire. c. CT shows extravasated contrast media in mediastinum. This patient was conservatively managed and needed no further treatment.

Figure 13. Complications - spinal cord infarction. A 75-year-old male with hemoptysis due to aspergillosis. Embolization of right lateral thoracic, right bronchial, and 5th and 6th intercostal arteries was performed. 
a. b. 5th and 6th intercostal arteriograms show neovascularization in right upper lung. Embolization of these arteries was done because the artery of Adamkiewicz was not visualized on angiograms prior to embolization. However, weakness of bilateral lower extremities appeared next morning. c. d. Axial and sagittal T2-weighted MR images show increased signal intensity (arrows) within the spinal cord at the T5/6 level, indicative of spinal cord infarction.

Conclusion
Bronchial and nonbronchial systemic artery embolization is a safe and effective nonsurgical treatment for patients with massive hemoptysis. Knowledge of bronchial artery anatomy, together with an understanding of the underlying pathologies, proper techniques, and complications, are essential for performing BAE.

References