Bronchial Artery Embolization

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Abstract

Keywords

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Hemoptysis represents a significant clinical entity with high morbidity and potential mortality. Most hemorrhages from a bronchial source arise in the setting of chronic inflammatory diseases. Medical management (in terms of resuscitation and bronchoscopic interventions) and surgery have severe limitations in these patient populations. Embolization procedures represent the first-line treatment for hemoptysis arising from a bronchial arterial source. This article discusses anatomical and technical considerations, as well as outcomes and complications, in the setting of bronchial arterial embolization in the treatment of hemoptysis.

Objectives: Upon completion of this article, the reader will be able to identify the etiologies, treatment options, and outcomes of patients with severe bronchial arterial bleeding.

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Case History

A 49-year-old woman with a history of pulmonary sarcoidosis presented to the emergency department complaining of multiple episodes of hemoptysis over the previous 24 hours. Chest radiography (►Fig. 1) and contrast-enhanced chest computed tomography (CT) (►Fig. 2A) revealed extensive bilateral bronchiectasis, particularly prominent in the apices, as well as mediastinal lymphadenopathy. CT angiography (CTA) demonstrated a prominent right intercostobronchial trunk (►Fig. 2B) originating from the aorta at the level of the left mainstem bronchus. Bronchoscopy demonstrated a bleeding source in the right upper lobe.

The patient was transported to the interventional radiology suite, the right femoral artery was accessed in standard fashion, and a 5F vascular sheath was placed. Aortography, including the arch and descending thoracic aorta, was per-

formed with a 5F pigtail catheter (►Fig. 3A). A branch of the right internal mammary artery was noted to overlie the right upper lobe, and a right bronchial artery was demonstrated. Using a 5F visceral selective catheter (Cook Medical Inc., Bloomington, IN), the descending thoracic aorta was interrogated in the vicinity of the left mainstem bronchus, and a right intercostobronchial artery was selected. Bronchial arteriography revealed hypervascularity in the right upper lobe, particularly within the lateral aspect of the lung apex (►Fig. 3B). A microcatheter and microwire were used to gain further purchase into this vessel, and it was embolized to near stasis using 500 to 700 micron particles in dilute contrast solution. The catheters were removed and a 5F catheter and standard guidewire were used to selectively catheterize the right internal mammary artery. Arteriography demonstrated an enlarged branch supplying the same region of hypervascularity in the right lateral apex (►Fig. 3C). This vessel was subselected using a microcatheter and microwire (►Fig. 3D), and embolized to near stasis using 500 to 700 micron particles (►Fig. 3E). Clinical follow-up for 2 years after the procedure has revealed no recurrent epihemoptysis.

Discussion

Bronchial artery embolization (BAE), first described by Rémy et al in 1973,¹ is now considered a first-line treatment for most cases of massive hemoptysis. Most commonly, these patients suffer from diffuse interstitial lung disease or chronic granulomatous disease such as cystic fibrosis, interstitial pulmonary fibrosis, bronchiectasis, tuberculosis, and fungal

Figure 1 Frontal chest radiograph reveals extensive, bilateral bronchiectasis, particularly prominent in the right apex (arrow).

infections such as aspergillosis. Less common causes of massive hemoptysis include aneurysms, arteriovenous fistulae, pulmonary embolism, and neoplasms ranging from small benign endobronchial lesions to large malignant tumors. BAE is an ideal first-line treatment because actively bleeding

Figure 2 (A) Contrast-enhanced computed tomography (CT), lung windows, better depicts diffuse bilateral bronchiectasis, most prominent in the right upper lobe (arrows). (B) Contrast-enhanced CT, soft tissue windowing, demonstrates a right intercostobronchial trunk (arrow) that was targeted for catheterization.

patients with poor underlying pulmonary function tend to be poor surgical candidates. In addition, unlike surgical resection, BAE often preserves pulmonary function. Because the risk of death in this population is by asphyxiation rather than hemodynamic instability, it is the clinical estimate of >300 cc of bloody output rather than hemodynamic status or hematocrit level that determine the indication and urgency of these cases. This article reviews the anatomy, methodology, and literature regarding BAE for the treatment of massive hemoptysis.

Anatomic Considerations and Imaging Work-Up

The bronchial arteries represent the source of massive hemoptysis in >90% of cases. A minority of cases result from nonbronchial systemic arteries or pulmonary arteries. Therefore, in most cases of massive hemoptysis, endovascular treatment begins with a search for bronchial arteries originating from their typical location: between the fifth and sixth thoracic vertebra² and fluoroscopically near the left main-stem bronchus on the frontal projection. The most common anatomical arrangement is two left and one right bronchial artery, but this configuration occurs in less than half of the general population. Left bronchial arteries typically originate from the aorta, whereas right bronchial arteries typically originate from an intercostobronchial trunk, as in the case presented here. Anomalous origins of the bronchial arteries is quite common. Hartmann et al evaluated the location of bronchial arteries using multidetector helical CTA in 214 patients and found that 36% had at least one bronchial artery of ectopic origin, most commonly from the caudal surface of the aortic arch.² A variety of other bronchial artery origins have been described, including the costocervical and thyrocervical trunks and the internal mammary artery. These vessels are distinguished from nonbronchial systemic arteries in that their branches follow the course of the bronchial tree. In up to 5% of cases of massive hemoptysis, long-standing parenchymal disease or neoplastic disease has led to the recruitment of an atypical systemic arterial supply to the lung parenchyma. Common systemic sources include intercostal, thoracic, phrenic, thyrocervical, vertebral, axillary, subclavian, and internal mammary arteries, as in the case presented here.

The potential alternative sources of hemoptysis raises some debate in the literature over the best initial angiographic approach in these patients. At minimum, thoracic aortography and catheter interrogation at the level of the typical origin of the bronchial arteries should be sufficient in >90% of cases. Routine catheterization and injection of the subclavian arteries has been suggested but is not without its risks.

CTA is gaining popularity as a preliminary study in many cases because this study can be obtained quickly, often during the preparatory period prior to bronchoscopy, and can provide valuable information regarding the location, type, and extent of the underlying pathology, the location of the extravasation, and the identification of systemic or anomalous arterial supply to the lung (—Fig. 4). This information can help determine the degree and location of catheter placement

Figure 3 (A) Aortogram, early arterial phase frontal projection, demonstrates a faint bronchial artery superimposed over the middescending thoracic aorta (open black arrow) as well as a prominent branch (white arrow) of the internal mammary artery superimposed over the right upper lobe. (B) Selective arteriography of the right intercostobronchial trunk shown in Figure 2A demonstrates supply to several intercostal arteries as well as a focus of hypervascularity (arrows) in the right lateral apex. This vessel was embolized with 500 to 700 micron particles injected through a microcatheter. (C) Selective arteriography of the right internal mammary artery demonstrates an enlarged branch (arrows) supplying the same hypervascular region previously embolized. (D) The internal mammary arterial branch was selectively catheterized with a microcatheter (arrow) and embolized with 500 to 700 micron particles. (E) Selective arteriography of the right internal mammary artery postembolization demonstrates stasis of this branch after embolization.

required to adequately demonstrate and treat all potential sources of hemoptysis. A review of CTA images has been shown to avoid unnecessary additional selective catheterization.² CT may also identify uncommon or subtle sources of hemoptysis such as endobronchial lesions, bronchial artery aneurysms, or pulmonary arterial sources such as Rasmussen aneurysms.

Bronchoscopy as a combined diagnostic and therapeutic tool may be indicated as a first-line therapy for massive hemoptysis, but it is controversial and often unnecessary

prior to BAE as a tool to localize the bleeding site if imaging can demonstrate the most likely source. In fact, bronchoscopy may delay definitive BAE and may have limited diagnostic and therapeutic value in some cases due to obscuration of the bronchial tree by blood. Radiography may adequately localize the site of bleeding in many cases, but in our experience, CT is superior to radiography in localizing the most likely source of bleeding (—Fig. 5) and is therefore a useful adjunct when radiography is indeterminate.

Figure 4 Computed tomography angiography with three-dimensional reconstruction of a patient with massive hemoptysis demonstrates a right bronchial artery (arrowhead) in its typical location, originating from the mid-descending aorta near the left mainstem bronchus (not shown). Three additional bronchial arteries (arrows) originate anomalously from the aortic arch, which is the most common source of anomalous bronchial supply.

Technique

In many cases of diffuse parenchymal disease, the exact site of hemorrhage is equivocal even after bronchoscopy and imaging studies. In addition, preliminary selective angiography often fails to demonstrate active parenchymal hemorrhage. Therefore, because massive hemoptysis is a life-threatening condition, multiple or all bronchial arteries are commonly treated to reduce the risk of recurrent or refractory bleeding. Following aortography from a femoral arterial approach, a visceral selective catheter is used to attempt catheterization

of the bronchial arteries. When successful, selected bronchial or intercostobronchial arteriography is performed to demonstrate any active extravasation, pseudoaneurysms, or most commonly, abnormally increased vascularity. In addition, findings that can increase the risk of BAE complications should be identified such as anterior medullary spinal arteries and large bronchial artery to pulmonary venous shunts. Subsequently, microcatheter subselection is performed to minimize the risk of vasospasm and to achieve sufficiently distal vascular access to prevent reflux of embolic agents into the aorta during embolization.

In most cases of hemoptysis caused by chronic interstitial lung disease or neoplasm, embolization is performed using particles. The progressive nature of these disease entities results in high rates of recurrence, and shutting the door, as it were, to future embolization procedures by embolizing the bronchial artery with coils prevents access for future embolization procedures. Liquid embolic agents have been evaluated preliminarily, but their use has not been fully evaluated due to concerns regarding tissue necrosis. The technical feasibility of ethylene vinyl alcohol copolymer³ has also been supported by preliminary reports, but data on long-term follow-up are not available. Recent long-term data using glue as an embolic agent are promising and discussed later.⁴

►**Fig. 6** illustrates the downside of using large-vessel permanent embolic agents. In this case, the bronchial artery was surgically clipped, and it was subsequently reconstituted by a thyrocervical branch that would be difficult to selectively catheterize for particle embolization. Coiling this vessel at the location of the surgical clip would yield the same undesired result. Exceptions include aneurysms or pseudoaneurysms of the bronchial or pulmonary arterial circulation as well as arteriovenous fistulae. We prefer the use of large particles (>500 microns) to minimize the risk of shunting to the

Figure 5 (A) Frontal radiograph of a patient with massive hemoptysis demonstrates marked diffuse bilateral bronchiectasis. The location and most likely source of the bleeding is difficult to discern. (B) Contrast-enhanced computed tomography (CT), lung windowing and coronal reconstruction, demonstrates the most prominent foci of cystic bronchiectasis to reside in the right lower lobe. (C) Bronchial angiography, midarterial phase, demonstrates a hypervascular region corresponding to the bronchiectasis noted on the CT.

Figure 6 (A) Images from a patient with massive hemoptysis illustrates why large vessel occlusion is not appropriate in these cases. Selective brachiocephalic arteriography, early arterial phase, demonstrates hypertrophied branches of the thyrocervical trunk (arrow). (B) Subclavian artery injection performed near the origin of the thyrocervical trunk. Markedly enlarged collateral branch from the thyrocervical branch(es) (arrow) reconstitute a surgically clipped main bronchial artery (arrowhead). (C) The reconstituted bronchial artery noted in (B) supplies a region of hypervascularity (arrow) in the right lung.

pulmonary venous circulation or distal embolization of the anterior medullary spinal circulation, although no literature study has evaluated an additional benefit of larger particles to prevent the complications of stroke or paralysis. Enlarged shunts from the bronchial arteries to pulmonary veins have been demonstrated in cases of extensive interstitial or granulomatous lung disease and, given the absence of evidence-based recommendations for a safe approach in such cases, in some cases preliminary embolization of such shunts using coils might be advisable prior to particle embolization. Embolization is performed to near stasis within the bronchial artery, and a gentle contrast injection should demonstrate marked pruning of the hypervascular branching pattern. Aggressive contrast injection after embolization should be avoided to prevent reflux of particles into the aorta.

Outcomes

Immediate clinical success rates for BAE using particles have been reported to range from 77% to 98%.⁵⁻⁷ Cremaschi et al evaluated 209 patients who had been embolized for hemoptysis and noted that immediate control of bleeding was achieved after BAE in 205 patients (98%).⁵ Recurrent bleeding despite apparently adequate embolotherapy remains a considerable problem. This should not be surprising given the chronic nature of the underlying inflammatory processes. Long-term recurrence rates have been reported to range from 9% to 55%. Barben et al evaluated 20 patients, of which 11 patients (55%) required more than one BAE, with a median time of 4 months between the first and second embolizations.⁷ Baltacıoğlu et al reported the results of using glue for BAE in 25 patients with hemoptysis.⁴ In these patients, initial clinical success was 100%, and after a mean follow-up of 14 months only three patients (12%) had recurrence after 30 days. Yoo et al used glue in 105 patients and demonstrated an immediate clinical success of 97.2% and a long-term recurrence rate of

only 20% after a mean of 28.5 months.⁸ Again, the risks of liquid embolic agents for BAE have not been fully evaluated, and particles remain the widely accepted first-line embolic agent.

Recurrent bleeding is influenced by the progressive nature of the underlying cause of hemoptysis. As a result, wide variability in underlying lung disease among cohorts in the literature results in wide variability in recurrence rates. Hirshberg et al studied the etiology, evaluation, and outcome of 208 patients with hemoptysis in a tertiary referral hospital.⁹ They found that the most common causes of hemoptysis included bronchiectasis (20%), lung cancer (19%), and bronchitis (18%). In contrast, older studies such as Rémy et al, reported the most common cause of hemoptysis to include tuberculosis.¹ Neoplasm is an uncommon indication for BAE and is most successful as a temporizing measure prior to surgical resection. Hayakawa et al demonstrated that neoplasm-induced hemoptysis demonstrated the highest failure rate with the worst long-term results.¹⁰

Complications

Serious adverse complications of BAE have been reported. Major complications include transverse myelitis, bronchial infarction, esophagobronchial fistula, ischemic colitis, transient cortical blindness, and stroke.^{7,11,12} Minor complications include transient chest pain and dysphagia. Of these complications, transient chest pain is the most common, with a reported prevalence of up to 89%.¹³

The most feared complication of BAE is spinal cord ischemia due to the inadvertent embolization of a spinal artery, fortunately occurring in <5% of cases in most studies. Anterior spinal arteries have the classic appearance of a cranial "hair-pin" turn followed by superimposition of the more distal segment over the spine on all projections. Angiography in more than one projection is typically performed when such a vessel is suspected, but extreme caution should be taken while

performing these studies, including double-flush technique and avoidance of prolonged catheterization or excessive probing of vessels that may contribute to the spinal supply. When an anterior spinal artery is identified by angiography, more distal arterial selection may be possible using a microcatheter, and extreme caution should be employed during injection of particles to avoid proximal reflux of particles. Tanaka et al performed a retrospective analysis of 47 patients: 22 patients were in the superselective group (embolization of the bronchial artery past the spinal and mediastinal branches) and 25 patients were in the non-superselective group (embolization at the origin of the bronchial artery). Within the non-superselective group, one patient (4%) developed spinal infarction,¹⁴ while none in the superselective group had such a complication. It should be noted that paralysis from BAE may also occur by inadvertent injury of the artery of Adamkiewicz during catheterization. Stroke as a complication of BAE may be underreported in the literature but is likely rare. This complication can occur due to the choice of particle sizes that are smaller than the size of the small vascular communications between the bronchial arterioles and pulmonary venous branches. The occasional case of transient cortical blindness after BAE may also result from passage of particles through these communications. Such channels are typically <300 microns in diameter. Authors have dismissed the risk of stroke as inconsequential even in the presence of bronchial artery to pulmonary venous communication on preliminary angiography.¹⁵ However, recent scattered case reports of stroke following BAE^{11,12} demonstrate the potential for this complication, the need for adequate preliminary angiography, and at a minimum the need for inclusion of this potential complication during the process of informed consent. Stroke can also result from traumatic catheterization of arch vessels during the search for contributing vessels such as systemic and anomalous bronchial arteries.

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