Bronchial Artery Embolization for Treatment of Life-Threatening Hemoptysis

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ABSTRACT

Massive hemoptysis is an emergent and life-threatening condition with a broad range of underlying causes. Fortunately, massive hemoptysis accounts for a minority of cases of hemoptysis, ~5%. Unlike hemorrhage in other areas of the body, the primary cause of death from pulmonary hemorrhage is most commonly asphyxiation rather than exsanguination. Given the limited capacity for the lung to preserve oxygen transfer in the setting of massive hemoptysis, a rapid and effective method for controlling hemorrhage is essential to minimize death in patients demonstrating respiratory compromise. Since its introduction in 1973, bronchial artery embolization has proven to be a safe and effective tool for the treatment of massive hemoptysis and is now considered the treatment of choice, with initial success rates ranging from 77 to 94%. The long-term control rate of hemoptysis ranges from 70 to 85% and is largely a function of the degree of inflammation and the natural progression of the underlying disease. This article reviews the current literature on bronchial artery embolization for the treatment of massive hemoptysis.

KEYWORDS: Hemoptysis, massive hemoptysis, bronchial artery embolization, embolization

Objectives: Upon completion of this article, the reader should understand the indications, technical aspects, and complications of bronchial artery embolization in the treatment of life-threatening hemoptysis.

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Massive hemoptysis is a life-threatening condition that can lead to asphyxiation and death. The definition of massive hemoptysis varies widely throughout the literature, ranging from 100 to 1000 mL/24 hours,¹ with the most commonly cited definition being 300 to 600 mL/24 hours.²⁻⁵ Although massive hemoptysis is relatively uncommon, accounting for ~5% of cases of hemoptysis, mortality rates as

high as 75% have been reported, with the most frequent cause of death being asphyxiation rather than exsanguination.⁶⁻⁸

Etiologies for massive hemoptysis are numerous and vary in frequency depending upon population demographics. Common causes include bronchiectasis, tuberculosis, chronic bronchitis, suppurative processes, and malignancy.^{2,9}

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INDICATIONS FOR BRONCHIAL ARTERY EMBOLIZATION: EMERGENT VERSUS URGENT TREATMENT

Because the primary concern for death in patients with massive hemoptysis occurs secondary to limitation of oxygen transfer, emergent (versus urgent) intervention should be considered at the earliest signs of hypoxemia and/or instability of vital signs, particularly in patients with limited pulmonary reserve secondary to underlying pulmonary disease. Factors associated with increased rates of mortality should be taken into consideration including increasing amounts of expectorated blood, increasing rate of blood loss, aspiration of blood in the contralateral lung, hypotension, poor underlying lung function, and underlying pulmonary carcinoma.¹ For patients in whom bleeding has ceased or decreased, emergent intervention may not be necessary. In emergent cases, transcatheter bronchial artery embolization has become the therapy of choice for massive hemoptysis. This is especially true given that surgical mortality rates have been shown to increase significantly in cases of emergent surgical intervention, ranging from 37 to 43%, in comparison to overall surgical mortality rates of 7 to 18%.¹⁰

BRONCHIAL ARTERY ANATOMY

The bronchial circulation is the source of massive hemoptysis in 90% of cases, with the remaining 10% divided equally between the pulmonary circulation (5%) and other systemic arterial supply to the lungs. In contrast to the pulmonary circulation, the bronchial circulation is under systemic pressure, arising from the descending aorta, most commonly between the levels of the T5 and T6 vertebrae.¹¹ Bronchial artery branches supply the esophagus, trachea, pericardium, hilar nodes, and visceral pleura. Although numerous anatomic variations of the bronchial circulation have been described, the majority of people have two to four bronchial arteries (Fig. 1).¹ Four classic origin variations were described by Cauldwell et al¹² in 1948. These are type 1 (40%): two on the left and one on the right, presenting as an intercostobronchial (ICBT) trunk; type 2 (21%): one on the left and one ICBT on the right; type 3 (20%): two on the left and two on the right (one ICBT and one bronchial artery); and type 4 (9.7%): one on the left and two on the right (one ICBT and one bronchial artery). Occasionally, they originate elsewhere in the aorta or in extra-aortic vessels such as the subclavian, thyrocervical, axillary, innominate, superior intercostal, pericardiophrenic, and inferior phrenic arteries. Internal mammary, coronary, and carotid arteries are less common.¹

TECHNICAL CONSIDERATIONS

A preliminary descending thoracic aortogram may provide useful information regarding bronchial artery

Figure 1 Common trunk to bilateral bronchial arteries (arrow). A single bronchial artery is identified on each side.

anatomy and nonbronchial systemic sources of bleeding.¹³

For selective catheterization, Cobra-type curved catheters (Cook, Bloomington, IN) are most commonly used although others such as Simmons-1, headhunter, Mikaelsson, or shepherd's hook (all manufactured by Cook) are also used. A 5F catheter is most often used to cannulate the origin of the bronchial arteries. Subselective embolization with a coaxial system with a 3F catheter (i.e., a microcatheter such as a Tracker system; Target Therapeutics, Fremont, CA) is recommended to prevent occlusion of the bronchial artery by the catheter and to bypass the proximal intercostal arteries, thereby avoiding potential spinal cord ischemia (Fig. 2). The coaxial system may also prevent reflux of embolic material into the aorta. In the setting of extensive atherosclerotic and/or tortuous vasculature, use of a guiding catheter (typically 7F) may be helpful in maneuvering the primary catheter and minimizing embolic complications.

The search for the bronchial arteries should begin at the T5 to T6 level and within or near the shadow of the left main bronchus where 94% of right and left bronchial artery origins are found.¹⁴

It is important to note that frank contrast extravasation is rarely observed in cases of hemoptysis because hemorrhage from bronchial arteries is usually intermittent and slow. Angiographic signs that suggest a source of bleeding include hypertrophied and tortuous bronchial arteries, particularly in cases of chronic inflammation, bronchial or peribronchial hypervascularity, systemic-to-pulmonary artery or venous shunting, and bronchial artery aneurysms. It should be noted that the hypervascularity shown on bronchial arteriogram does not consistently predict the site of bleeding. In addition, pulmonary angiography may demonstrate aneurysms (e.g., Rasmussen's aneurysm in cavitary tuberculosis and mycotic aneurysms resulting from drug abuse).

Figure 2 A patient with history of renal cell carcinoma, metastasizing to the mediastinum, presented with an erosive lesion into the left main stem bronchus. (A) Initial diagnostic angiogram demonstrated a right intercostal bronchial trunk (ICBT) with its origin at the inferior aspect of the distal aortic arch. This was noted to have direct feeding vessels to the subcarinal mass. A left bronchial artery (not shown) was interrogated and found to have no direct feeding supply to the mediastinal tumor. (B) The right ICBT was then embolized with a coaxial system using an outer 5F Cobra catheter (arrow) and an inner 3F microcatheter (arrowhead). Polyvinyl alcohol particles (500 to 700 μm) were utilized as the embolic agent. (C) Postembolization angiogram demonstrated cessation of flow (arrow) to the tumor mass as well as the right bronchial artery.

In the case that abnormal bronchial arteries are not identified, arch aortography and selective arteriography should be performed to identify anomalous bronchial arteries and/or nonbronchial systemic arterial supply (Fig. 3). If lower lobe disease is present, an abdominal aortogram and examination of the inferior phrenic arteries should also be performed. If no systemic arterial source is identified, selective pulmonary arteriography should be conducted to evaluate for pulmonary pseudoaneurysm or arteriovenous fistula, particularly in

patients with cavitary lung disease or a history of recent Swan-Ganz catheterization (Fig. 4).

When performing bronchial arteriography and embolization, every attempt should be made to identify the arterial supply of the spinal cord, as the most serious complication of bronchial arteriography and embolization is spinal cord ischemia. The largest anterior medullary branch supplying the anterior spinal artery (the artery of Adamkiewicz) is most commonly found between T9 and T12 (74%). In 15% of cases it is found

Figure 3 A 62-year-old woman with chronic obstructive pulmonary disease and bronchiectasis presented with recurrent hemoptysis, status post prior bronchial artery embolization. Thoracic aortogram revealed no bronchial artery. (A) The left internal mammary artery (ima) was evaluated and shown to supply tortuous, irregular vessels (arrowheads) to the left lingula. (B) These abnormal branches were embolized with polyvinyl alcohol particles using a coaxial system with an inner microcatheter (arrows).

Figure 4 A 22-year old woman with a history of lymphangiomas and hemangiomas presented with recurrent hemoptysis. She had previously undergone right lower lobe resection. Evaluation of the pulmonary and bronchial arteries was unremarkable. An arteriovenous fistula (long arrow) was found involving the distal portion of a right internal mammary arterial branch (ima). It was uncertain whether the fistula connected to the pulmonary artery or vein (arrowheads). This was likely postsurgical in nature.

between T5 and T8, and it is known to arise from the right ICBT in 5% of the population.¹⁵ Left bronchial arteries and other systemic arteries rarely supply the anterior spinal artery. The classic angiographic appearance of the spinal artery is a “hairpin” loop overlying the vertebral column (Fig. 5).

Nonionic contrast is recommended to minimize the cough response and to lower the risk of spinal cord injury.^{16,17} Additionally, a short-acting barbiturate such as amobarbital or lidocaine solution can be injected

Figure 5 Injection at the origin of the right superior intercostal artery demonstrated an anterior spinal artery arising from it, with the characteristic hairpin loop appearance (arrows).

intra-arterially as a provocative test to detect an occult spinal artery branch before bronchial artery embolization.^{18,19} The use of somatosensory evoked potentials to monitor spinal cord ischemia during bronchial artery embolization has been reported in the literature but is not routinely practiced.²⁰

The most frequently used embolic materials are gelfoams and polyvinyl alcohol (PVA) particles. The disadvantage of gelfoams is its resolvability leading to recanalization. PVA particles (greater than 350 μm in diameter), on the other hand, are permanent embolic agents. A recent study by Corr³ also demonstrated promising short-term results using gelatin cross-linked acryl microspheres (500 to 750 μm) (Embospheres; Biosphere Medical, Osaka, Japan) for embolization of life-threatening hemoptysis. Particles smaller than 350 μm should be avoided as they can pass through bronchial artery-pulmonary artery anastomosis and cause pulmonary infarction, or pass through bronchial artery-pulmonary vein anastomosis and cause systemic artery embolization.^{5,11,21,22} Similarly, liquids such as ethanol or fine particles (gelfoam powder) can produce distal embolization and occlusion of the capillary bed, leading to possible tissue infarction, and should be avoided.

As previously mentioned, enormous bronchial arteries with high flow and large systemic-to-pulmonary shunts are sometimes encountered, particularly in cystic fibrosis, in which case the use of coil embolization may be required for safe and adequate occlusion.^{23,24} Because preservation of the proximal part of any abnormal vessel may be important for future embolization access in cases of recurrent bleeding, this type of proximal coil occlusion should not be considered routine practice and should only be employed when other methods fail or are contraindicated, or when the patient's clinical condition demands very rapid control. A study by Ishikawa et al²⁵ introducing the use of interlocking detachable coils for the treatment of massive hemoptysis demonstrated improvement in long-term success rates versus traditional non-interlocking detachable coils (92.3% versus 83.7%, respectively).

RESULTS

Bronchial artery embolization is a very effective technique for the immediate control of massive hemoptysis, with a success rate in the range of 77 to 94%.^{3,9,26-29} Overall, the long-term control rate of hemoptysis is ~70 to 85% and is largely a function of the natural progression of the underlying disease.^{2,9,29,30} Recanalization of the embolized vessels or achievement of only partial embolization also contributes to recurrence of hemoptysis. In a study of 101 patients who received embolization for the treatment of massive or continuing moderate hemoptysis, Kato et al³¹ concluded that the most significant factor affecting long-term outcome was the

Figure 6 A 48-year-old male with a history of metastatic plasmacytoma presented with hemoptysis. A right intercostal artery was selectively cannulated at the level of the carina, supplying multiple areas of abnormal blush, including a peripheral area (arrows) feeding the pleural thickening.

degree of inflammation caused by the underlying disease. Interestingly, the degree of hemorrhage and the severity of angiographic findings were not statistically significant factors affecting outcome. A study by Tamura et al³⁰ demonstrated that the presence of pleural abnormalities significantly lowers the long-term effectiveness of bronchial artery embolization, decreasing the long-term success rate from 70% in those without pleural thickening to 29% in patients with significant pleural thickening (Fig. 6).

Although the scope of this article is limited to the topic of emergent treatment of massive hemoptysis, bronchial artery embolization has also been shown to be effective in the treatment of nonmassive hemoptysis, particularly in cystic fibrosis. Antonelli et al³² found that in patients with cystic fibrosis who presented with minor hemoptysis, those who underwent early bronchial artery embolization in combination with medical treatment had significantly fewer bleeding episodes and better quality of life over the following 3 years compared with those managed with medical therapy alone.

COMPLICATIONS

Complications of bronchial artery embolization include chest pain (24 to 91%) and dysphagia (0.7 to 18.2%), which can occur 2 to 7 days after embolization.³³⁻³⁵ These symptoms usually regress. Subintimal dissection of aorta or bronchial artery can also occur but is frequently asymptomatic. Pulmonary infarction can complicate bronchial embolization when the bronchial artery

is the only source of vascular supply to the lung, as in the case of chronic proximal pulmonary artery occlusion. The most devastating complication is spinal cord ischemia following inadvertent occlusion of the anterior spinal artery. Careful analysis of the angiogram, before and during the embolization procedure, is crucial to prevent this complication. Transverse myelitis has also been reported after diagnostic bronchial arteriography with the use of ionic hyperosmolar contrast agents.^{16,17} The risk of this contrast-induced neurotoxicity can be minimized with the use of diluted nonionic contrast medium. Other rarely reported complications include bronchoesophageal fistula, bronchial infarction, posterior circulation cerebral infarction, diaphragmatic paralysis, ipsilateral forehead and orbital pain, transient cortical blindness, and ischemic colitis.³⁶⁻⁴⁴ To minimize the risk of complications due to pulmonary and systemic infarction, particles smaller than 350 μm , liquids such as ethanol, and fine particles (gelfoam powder) should be avoided.

ALTERNATIVE THERAPIES

Although bronchial artery embolization is the treatment of choice for massive hemoptysis, in cases where embolization is unavailable or contraindicated, other treatment options are also available. Surgical resection is generally reserved for failed embolization or for recurrent massive hemoptysis following multiple prior embolizations.^{2,5,45} In surgical cases, preoperative bronchial artery embolization has also been shown to reduce postoperative mortality.¹⁰ Endobronchial tamponade with fiberoptic bronchoscopy has been shown to be of use in patients who are not suitable candidates for bronchial artery embolization or surgery.⁴⁶ Double-lumen endotracheal tubes can be used to isolate each main-stem bronchus and protect aspiration of blood into the contralateral nonbleeding lung; however, misplacement and difficulty maintaining proper placement are frequent obstacles in their use. Endobronchial infusion of thrombin and fibrinogen-thrombin has been used with relatively good success as well as intravenous treatment with vasopressin.^{47,48} Laser photocoagulation and argon plasma coagulation are generally limited to patients with hemorrhage from endobronchial lesions.

CONCLUSIONS

Massive hemoptysis is an emergent and life-threatening condition with a high mortality rate. Bronchial artery embolization is a safe and effective method of treatment for massive hemoptysis with a high initial rate of success. Advancements in angiographic equipment and technique continue to improve success rates, and with careful technique, it can be performed safely and with minimal risk.

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