



Review Article

Bronchial Artery Embolization

Devendra Singh Bisht*, RK Gokhroo*

*Department of Cardiology, J.L.N Medical College, Ajmer

Bronchial artery embolization is often used as a therapeutic modality to treat patients' suffering from haemoptysis. First bronchial artery embolization was done by Remy et al in 1973. Historically, surgery had been considered as the definitive therapy for patients suffering from haemoptysis. Unfortunately, surgical intervention carries a mortality of 18% when performed electively, rising to 40% when performed emergently.¹

Anatomy of Bronchial Arteries

Bronchial arteries are small calibre vessels that arise from the descending thoracic aorta. Bronchial arteries supply blood to the airways of the lung, oesophagus, lymph nodes^{2,3,4} and show substantial anatomic variations with respect to their origins, courses and branching patterns. Among the bronchial arteries the right intercostobronchial trunk, which arises from the right posterolateral aspect of the thoracic aorta, is the most constant vessel.^{3,4,5}

On the left side, the bronchial arteries usually originate from the anterior surface of the descending thoracic aorta, then it pass forward beside the lateral wall of the oesophagus, and cross the peribronchial space from the level of the left main bronchus toward the hilum^{2,3,5,6}

Two types of bronchial arteries has been described in literature-

1. Orthotopic bronchial arteries
2. Ectopic or anomalous bronchial arteries

1. Orthotopic bronchial arteries

A bronchial artery is said to have an orthotopic origin when it originates from the descending aorta at the level of the fifth or sixth thoracic vertebra.

Four types of classic bronchial artery branching patterns have been described (figure 1):

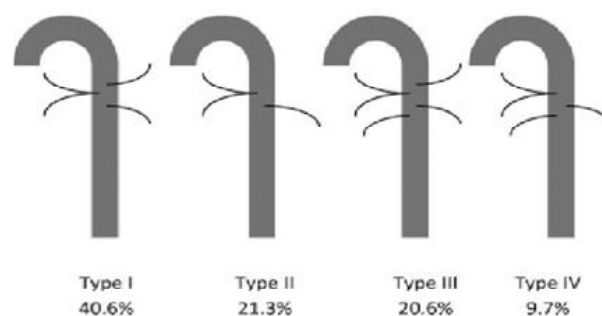


Fig. 1 : The 4 most prevalent patterns of bronchial artery anatomy. Type I: single right bronchial artery via intercostobronchial trunk (ICBT), paired left bronchial arteries. Type II: single right bronchial artery via ICBT, single left bronchial artery. Type III: paired right bronchial arteries with one from ICBT, paired left bronchial arteries. Type IV: paired right bronchial arteries with one from ICBT, solitary left bronchial artery. (adopted from David R. Sopko, Tony P. Smith: seminars in interventional radiology/volume 28, number 1 2011)

1. One right intercostobronchial trunk and two left bronchial arteries (40%);
2. One right intercostobronchial trunk and one left bronchial artery (21%);
3. One right intercostobronchial trunk, a right bronchial artery, and two left bronchial arteries (20%);
4. One right intercostobronchial trunk, a right bronchial artery, and one left bronchial artery (10%).

Hence in approximately 60-70% of cases, there are two left bronchial arteries, where the upper left bronchial artery appears to follow a horizontal course within the mediastinum. Occasionally, right and left bronchial arteries arise from the aorta as a common trunk.

Address for Correspondence :

Dr. Devendra Singh Bisht, Deptt. Of cardiology, J.L.N. Medical College, Ajmer



2. Ectopic or anomalous bronchial arteries

A bronchial artery is said to an ectopic origin when its origin is outside the T5 or T6 vertebral levels of descending thoracic aorta. These ectopic bronchial arteries can originate from-

1. The aortic arch
2. Intercostal arteries
3. Brachiocephalic trunk
4. Subclavian artery
5. Thyrocervical trunk
6. Internal mammary artery
7. Inferior phrenic artery (abdominal aorta)

In some patients '**Nonbronchial Systemic Arteries**' supplying the lung inflammatory lesion can be a source of haemoptysis. These arteries can be-

1. Branches of subclavian and axillary arteries
2. Intercostal arteries
3. Internal mammary
4. Thyrocervical trunk
5. Inferior phrenic arteries

Nonbronchial systemic arteries should be suspected as a source of haemoptysis, if CECT imaging show pleural thickening of >3 mm and tortuous enhancing vascular structures within hypertrophic extra pleural fat.

Causes of Massive Haemoptysis and Causes of Bronchial Artery Aneurysm

Pulmonary causes		Cardio-vascular causes	Miscellaneous
Airway diseases	Parenchymal diseases	1. AVmalformation 2. Bronchial artery aneurysm 3. Pulmonary embolism 4. Pulmonary artery hypertension 5. Ruptured thoracic artery aneurysm 6. Aortobronchial fistula	1. Trauma 2. Coagulopathy 3. Iatrogenic 4. Foreign body
1. Bronchiectasis 2. Bronchogenic carcinoma 3. Bronchitis	1. Tuberculosis 2. Cystic fibrosis 3. Aspergillosis 4. Histoplasmosis 5. Pneumonia 6. Lung abscess 7. Pneumoconiosis 8. Vasculitides		

Among all the causes of haemoptysis pulmonary tuberculosis, bronchogenic carcinoma, bronchiectasis and cystic fibrosis are the common causes of massive haemoptysis.

Bronchial artery aneurysm is considered to be caused by bronchiectasis, mycotic origin, or Osler-Weber-Rendu syndrome. When aneurysmal dilatation of the bronchial artery is caused by trauma, it is called a "pseudoaneurysm." The bronchial artery aneurysm may be present in the mediastinum or in the lung.

Diagnosis

Chest X ray is considered as a useful and basic diagnostic modality in the evaluation of haemoptysis but ability of chest radiography to accurately localize the disease process is highly variable, and can be normal in up to 30% of patients suffering from haemoptysis.⁷⁻⁹ Further the accurate Localization can be particularly difficult due to either opacification of both lungs during episodes of massive haemoptysis

or in the setting of bilateral disease.

Bronchoscopy is a better diagnostic modality to localize and potentially treat the source of haemoptysis.^{10,12} Traditionally, rigid bronchoscopy is preferred due its superior ability to maintain the airway and provide a robust lumen for suction of large volume haemoptysis; however, it is limited by decreased portability and the requirement for general anesthesia. Flexible, or fiberoptic bronchoscopy is readily available at the bedside, retains the ability to instill medications or perform other therapeutic interventions, and does not necessitate anesthesia making it the preferred bronchoscopic technique as shown in a recent survey of pulmonologists that found 79% preferred the flexible to the rigid bronchoscope.^{13,14}

The pitfalls of bronchoscopy are that it is plagued by a frequent inability to identify the underlying cause of haemoptysis, and fails to localize the bleeding site in 50% of examinations.^{9,11} further if the cause and location of haemoptysis can be determined by chest X ray, then there is no further benefit associated with bronchoscopy in patients considered acceptable for

bronchial artery embolization.¹¹

Multi detector computed tomography (MDCT)

For the imaging of bronchial and nonbronchial systemic arteries as a source of haemoptysis, helical CT using an MDCT scanner is preferred to image the thorax from the supraclavicular level to the upper pole of the right kidney in a single breath-hold.^{14,15} Afterwards multiplanar reconstruction is done at various angles to evaluate the mediastinal course of bronchial arteries and to trace them to the hilum.

The features which suggests bronchial arteries as a source of bleed are; bronchial artery diameter > 2 mm and its traceability to hilum. Yoon et al.¹⁵ demonstrated that, bronchial arteries causing haemoptysis are traceable to the hilum even when they are smaller than 2 mm in diameter. Extravasation of contrast medium, a specific sign of bronchial bleeding, is occasionally seen.¹⁶

On the contrary, the features which suggests nonbronchial systemic arteries as a source of bleed are; enlarged vascular structures (one or several branches of the subclavian or axillary arteries, the intercostal arteries, or the inferior phrenic arteries) within extrapleural fat, pleural thickening (? 3 mm) and lung parenchyma abnormalities.

By providing thin-section transaxial, multiplanar reconstruction, and 3D images, CT angiography using MDCT allows comparable or better images than conventional angiography with respect to the depiction of bronchial or nonbronchial systemic arteries. CT angiography is particularly useful for visualizing the ectopic origin of bronchial arteries and nonbronchial systemic collateral arteries.^{14, 15}

Indications for bronchial artery embolization

1. Failure of medical treatment to control bleeding
2. Moderate haemoptysis (≥ 3 episodes of ≥ 100 mL blood within 1 week) to massive haemoptysis (≥ 300 mL expectorated blood/ 24-hours)
3. Chronic mild haemoptysis with increasing episodes
4. Recurrent haemoptysis
5. To Stabilize patients before definitive treatment (surgery)
6. As a definitive therapeutic approach in patients in whom surgery couldn't be done

Procedure

Angiography and intervention are performed under either moderate sedation or general anesthesia, as

dictated by the clinical presentation and status of the patient. The interventional suite should be equipped with DSA technology. The goal of bronchial artery embolization is to find the bleeding vessel and to plug it with embolizing material.

Catheters

The 4, 5, or 5.5 Fr size catheters are commonly used depending upon the anatomy of bleeding vessel and size and type of embolizing material used.

1. Reverse-curved catheters
 - a. Mikaelson
 - b. Simmons I
 - c. SOS Omni
 - d. Sidewinder
 - e. Headhunter
2. Forward-looking catheters
 - a. Cobra
 - b. HIH
 - c. Right coronary catheter

Embolizing materials

The criterion of choosing embolizing agent includes its ease of delivery, durability of occlusion, propensity for recanalization, and size. The size of embolizing agent is determined by the site of desired vessel occlusion (proximal or distal) and the catheter lumen used for delivery. The diminutive size of embolizing material results in very distal embolization occluding at the end-arteriolar level, which may result in ischemic complications to the bronchi, oesophagus, or vascular structures.¹⁷ secondarily, shunting of small embolic agents into the pulmonary venous system and then into the left heart may lead to systemic arterial embolization. On the contrary, embolization with agents that occlude proximally may produce a suboptimal result due to the propensity to form collaterals around the occlusion site. So, the choice of agent is critical to the success and safety of the procedure. The embolic agents used are-

1. Absorbable gelatin sponge (Gelfoam1, Pharmacia and Upjohn, Kalamazoo, MI)
2. Polyvinyl alcohol (PVA) particles (e.g., Contour 1 PVA Embolization Particles, Boston Scientific, Natick, MA)
3. Microspheres (e.g., Embosphere 1 Microspheres, BioSphere Medical, Rockland, MA)
4. Liquid embolic agents
 - a. N-butyl 2-cyanoacrylate (NBCA; e.g., TruFill 1 n-BCA Liquid Embolic System, Johnson and Johnson/DePuy, Raynham, MA)
 - b. Ethylene vinyl alcohol polymer (Onyx 1 Liquid

Embolic System, eV3 Neurovascular, Irvine, CA)

- 5. Ethylene vinyl alcohol polymer
- 6. Metallic coils

Technique of bronchial artery embolization

Bronchial artery embolization is commonly done through femoral arterial route. Brachial artery access may be used to address extraordinarily difficult nonbronchial systemic arterial contributions. It is, however, felt to be associated with higher morbidity and complication rates.¹⁸⁻²¹ After obtaining arterial access with the help of pigtail catheter descending thoracic aortogram is taken in left anterior oblique (LAO) view. The upper end of pigtail should be at the level of carina for proper visualization of bronchial

arterial anatomy. At our institution, all imaging procedures are preferentially performed via a 5 French diagnostic catheter. For intervention we use 6 french catheter for the ease of embolizing bleeding vessels. All arteriography should be performed with either low-osmolar or iso-osmolar nonionic contrast material, as high-osmolar contrast has been implicated in transverse myelitis.^{22,23} Many advocate initial thoracic aortography to delineate the number, size, and position of the bronchial arteries.²⁴⁻²⁶ This is particularly helpful in cases of aberrant or ectopic bronchial arteries. The clues that suggest thoracic artery as the potential source of bleeding are-

- 1. Hypertrophic and tortuous bronchial arteries
- 2. Parenchymal hypervascularity and neovascularity
- 3. Shunting of blood between pulmonary artery and vein

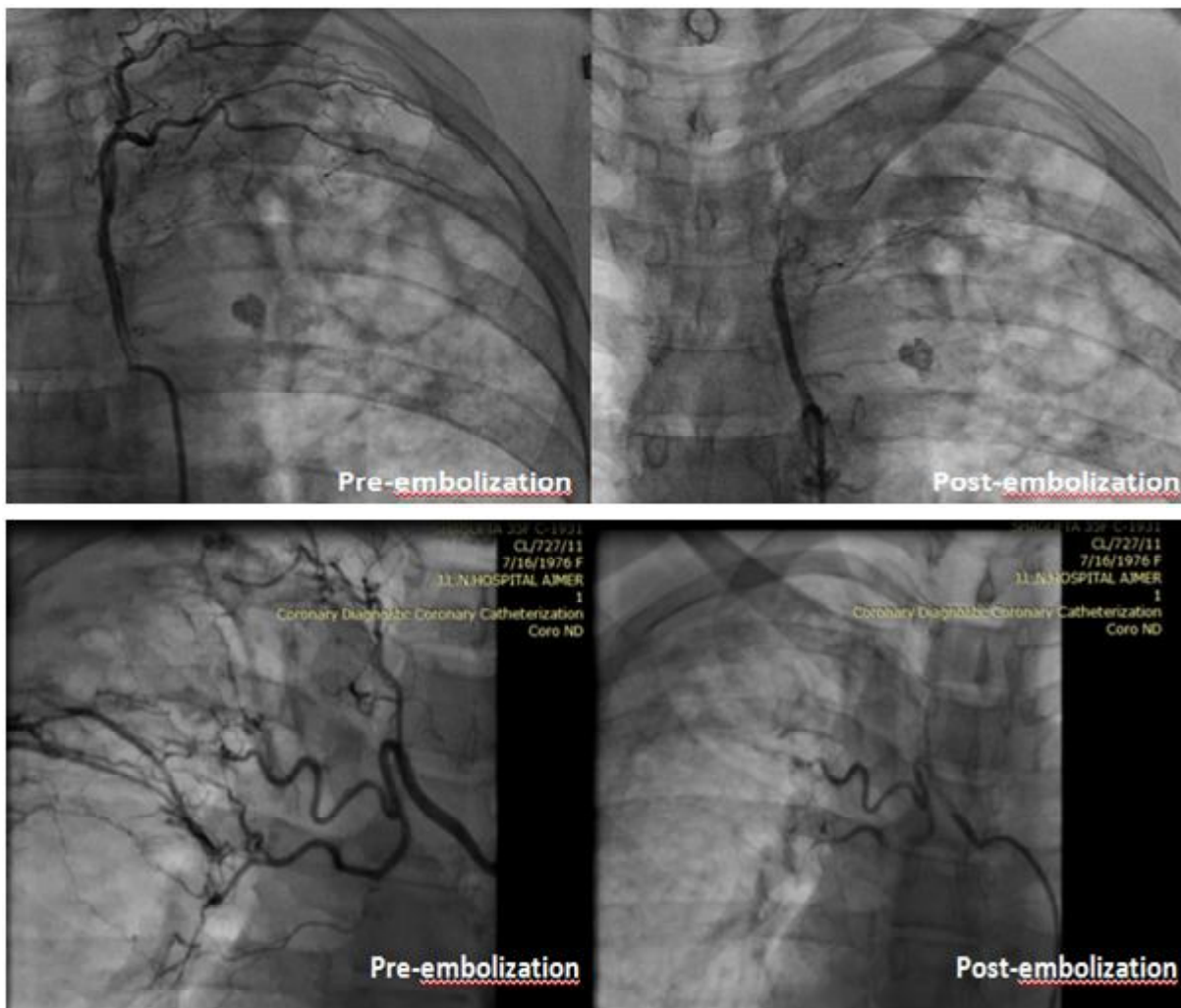


Fig. 2 : Cine-images from 2 different patients showing complete loss of hyper-vascularity after bronchial artery embolization.

4. Aneurysmal dilatation of bronchial artery
5. Extravasation of contrast in lung parenchyma (uncommon)

Micro catheters are frequently used now a days to increase coaxiality and to perform super selective cannulation and administration of embolic agents.^{27,28,35} Special attention to be given when negotiating an intercostobronchial trunk beyond the intercostal moiety that may give rise to the aforementioned anterior spinal artery. Hand injection of contrast is best executed with 10ml syringes capable of generating adequate pressures to achieve the flow rates necessary for satisfactory vascular opacification. Transpleural angiogenesis occurs in the setting of chronic inflammatory or neoplastic conditions, hence a thorough investigation of these vessels should be done at initial presentation, because of their potential to result in recurrent haemoptysis.^{29,30,35,36}

In up to 5% of patients presenting with haemoptysis, the pulmonary artery is the culprit bleeding vessel. Hence, in patients with disease known to result in direct pulmonary arterial injury such as tuberculosis, lung abscess, iatrogenic trauma, or malignancy, bronchial artery embolization may not achieve adequate clinical resolution.^{32,35} These subsets may present with haemoptysis classified as "early" recurrence. In these patients both nonbronchial systemic as well as

pulmonary arterial investigation should be performed.

In some patients aneurysm and pseudoaneurysm may contribute to pulmonary arterial hemorrhage and haemoptysis. Rarely, in a patient with hereditary hemorrhagic telangiectasia rupture of a congenital pulmonary arteriovenous malformation may result in haemoptysis.³⁴

Outcome

The success rate of bronchial artery embolization ranged from 65 to 100% with recurrent non-massive bleed noted in 16-46% of patients. Recurrence of haemoptysis may be due to incomplete embolization of the bronchial vessels, recanalization of the embolized arteries, presence of nonbronchial systemic arteries, or development of collateral circulation in response to continuing pulmonary inflammation. Bronchial artery embolization is also successful in patients of cystic fibrosis suffering from haemoptysis.

Technical failure noted in 13% of patients and it is caused by non-bronchial artery collaterals from systemic vessels such as the phrenic, intercostal, mammary or subclavian arteries.

Complications of bronchial artery embolization

Bronchial arteries supply blood not only to airways of lung but also to oesophagus, diaphragmatic and

Authors	Year	N	Embolic Material	Immediate Clinical Success%	Clinical Recurrence%	Complication Rates%
Swanson et al	2002	54	Coils. PVA; gelatin sponge	94	24.1	7
Mel et al	1999	56	Gelatin sponge; tris-acryl microspheres; deca mater; PVA; bucrylate	77	55.3	12
Ramakentan et al	1996	140	Gelatin sponge	73	27.1	27.8
Katoh et al	1990	33	PVA with gelatin sponge	–	21.2	6
Rabkin et al	1987	306	Polyurethane particles; albumin macroaggregates; penicillin or 10% NaCl	90.8	33.7	0.3
Uflacker et al	1983	33	Gelatin sponge	100	18.2	3
Uflacker et al	1985	64	Gelatin sponge; e-amino-caproic acid; cellulose sponge; EtOH	76.6	21.4	10.9
Remy et al	1977	104	Gelatin sponge	84	28.6	11.5
Baltacioglu et al	2010	25	n-BCA	100	16	16
Corr et al	2005	70	tris-acryl microspheres	87	13	8.6
Chun et al	2010	50	PVA	86	28.0	14
Keto et al	2000	101	PVA; Gelatin sponge; coils	94	37.5	5.9
Poyanli et al	2007	140	PVA; coils	98.5	10	0
Hayakawa et al	1992	58	Gelatin sponge	86.2	28	6.9

N, number of patients; PVA, polyvinyl alcohol; NaCl, sodium chloride; NBCA, n-butyl cyanoacrylate; EtOH, ethanol

Outcomes of Bronchial Artery Embolization for Haemoptysis in different studies (adopted from David R. Sopko, Tony P. Smith: seminars in interventional radiology/volume 28, number 1 2011)¹³

mediastinal pleura, spinal cord and mediastinal lymph nodes. The complications arise due to inadvertent occlusion of these vessels. Most common complications are chest pain (25-90%), and dysphagia (1-20%). These complications are usually self-limiting in the vast majority of cases.^{37,38,39} Major complications are transverse myelitis leading to paraparesis, intimal tears, pyrexia, systemic embolization in other organ systems and vessel perforation. Superselective cannulation of bronchial arteries has reduced the number of cases.⁴⁰ Cortical blindness has been reported and represents an extraordinarily rare neurologic complication. The predominant proposed pathway is from unintentional embolization of the occipital cortex in the setting of fistula formation arising from the bronchial artery to either the pulmonary veins or the vertebral arterial distribution.⁴¹ Other rare complications include bronchial stenosis, necrosis, and bronchoesophageal fistula presumably due to bronchial wall ischemia as well as ischemic necrosis of the aorta with or without associated dissection.^{41,42,43} Pulmonary infarction and ischemic colitis have also been described, all of these consisting of isolated case reports.⁴⁴

Conclusions

Because of high mortality rate associated with surgery, bronchial artery embolization is often used as a therapeutic modality to treat patients suffering from haemoptysis. This treatment modality warrants a well integrated multidisciplinary approach. Bronchial artery embolization as a sole therapy carries a high success rate coupled with low complication rate. Because of its minimal invasiveness it can be repeated in terms of recurrence.

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