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Bronchial Artery Embolization to Control Hemoptysis: A Review

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Abstract. Bronchial artery embolization has become an established technique in the management of massive or recurrent hemoptysis. The clinical background, methods, and results of this procedure are discussed, as are the potential complications and their prevention.

Key words: Bronchial artery—Hemoptysis—Pulmonary hemorrhage—Embolization—Transverse myelitis

Bronchial artery embolization is now used routinely in the management of massive or recurrent hemoptysis [1, 2]. Hemoptysis is always an alarming event and, when massive and untreated, has a mortality rate of greater than 50% [3]. It has been shown that safe and rapid control of hemoptysis usually can be obtained by therapeutic embolization of the bronchial arteries when the source is systemic blood supply to the lungs. This may either provide definitive therapy or stabilize the patient in preparation for surgery.

Historical Perspective

Bronchial arteries were known to exist since before the time of Galen, and are said to have been illustrated first by Leonardo da Vinci [4]. Radiologists' interest in the systemic circulation of the lung dates back to the late 1950s and early 1960s when Williams et al. [5] and Neyazaki [6] reported using nonselective thoracic aortography to visualize the bronchial arteries in pulmonary disease. In 1963, Viamonte [7] performed the first selective bronchial arteriogram. During the subsequent decade, selective bronchial arteriography was used to help differentiate benign from malignant pulmonary masses and to determine the extent of bronchiectasis [7–10]. Unfortunately, a number of patients developed transverse myelitis as a result of this procedure [11, 12]. Investigation of this complication led to a better understanding of the arterial supply to the spinal cord and to improvements in angiographic technique [13]. The first bronchial artery embolization for control of hemoptysis was performed in France by Remy et al. in 1973 [14], and this was followed in the United States by Wholey et al. [3] who reported on their experience in 1976. Since these early reports, various authors have discussed results and techniques in over 500 cases of bronchial artery embolization.

Anatomical Considerations

The bronchial arteries are the primary nutrient channels of the lung [15]. They extend along the bronchi to the level of the respiratory bronchus where they anastamose with the pulmonary circulation [16]. Branches of the bronchial arteries supply the vasa vasorum of the pulmonary vasculature as well as the diaphragmatic and mediastinal portions of the visceral pleura [4, 16]. In the mediastinum, the bronchial arteries supply the middle third of the esophagus and the subcarinal lymph nodes [4]. Venous return from the central bronchi occurs via bronchial veins which drain into the azygous vein, hemiazygous vein, or directly into the superior vena cava [4]. However, most of the venous return occurs through the pulmonary veins by way of the bronchopulmonary anastamoses [4, 16]. The pulmonary architecture can also receive systemic blood supply from small vessels in the pulmonary ligament or from chest wall collaterals that cross pleural adhesions.

The origin of bronchial arteries is quite variable. Approximately 70% arise from the descending tho-

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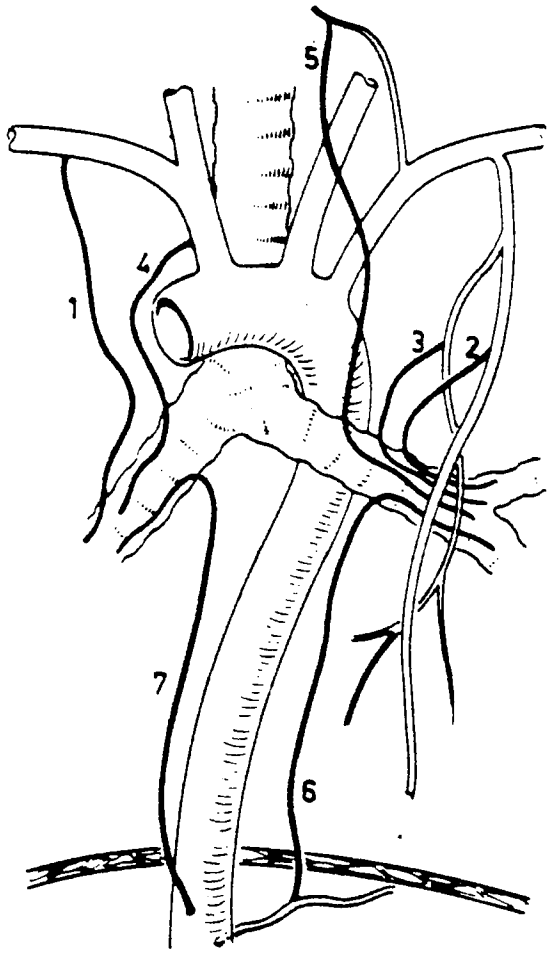

Fig. 1. Most common forms of aberrant origin of the bronchial arteries: (1) subclavian, (2) internal thoracic, (3) pericardiacophrenic, (4) innominate, (5) thyrocervical trunk, (6) inferior phrenic, and (7) abdominal aorta. Reprinted from [4] with permission.

racic aorta between the cranial margin of T5 and the caudal margin of T6 [4, 15]. Up to 20% have an aberrant origin and arise from various other vessels [4] as illustrated in Figure 1. The remaining 10% originate from the anterior surface of the aortic arch or from the remaining portions of the descending thoracic aorta. In most cases, a right bronchial artery arises from an intercostobronchial trunk [4, 15] which usually supplies the first intercostal branch on the right side and originates from the anteromedial surface of the aorta [17]. Intercostobronchial trunks are uncommon on the left side and most left bronchial arteries arise from the anterior surface of the aorta. Independently arising right bronchial arteries also originate from the anterior surface of the aorta as do common trunks, which divide to supply a bronchial artery to each lung. The four most common patterns of origin are illustrated in Figure 2.

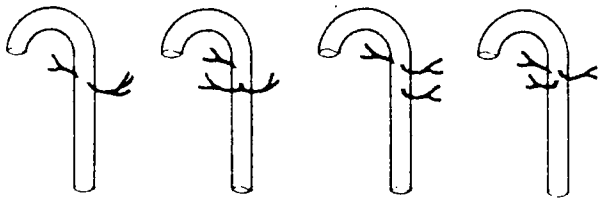

Fig. 2. Representation of the most common types of origin of the bronchial arteries. The right intercostobronchial trunk arises from the posteromedial surface of the aorta, whereas the remaining bronchial arteries arise anteriorly. Reprinted from [1] with permission.

The vascular supply of the thoracic spinal cord must be considered when performing bronchial arteriography [13]. The anterior portion of the cord is supplied by the anterior spinal artery which runs in the ventral median sulcus. This vessel originates from branches of the vertebral arteries and receives blood from anterior medullary branches of intercostal and lumbar arteries [18]. The anterior medullary arteries course steeply upward through the intervertebral foramina before turning sharply in the caudal direction to join the anterior spinal artery. In the thoracic region, the anterior spinal artery is usually supplied by a single anterior medullary branch which may originate from the right intercostobronchial trunk [18]. The largest anterior medullary branch is the arteria radicularis magna, also known as the artery of Adamkiewicz. This vessel usually arises between T8 and L4 but may originate as high as T5 [4]. The posterior portion of the cord is supplied by paired posterior spinal arteries which run along the posterolateral surfaces of the spinal cord. These vessels are fed by posterior radicular arteries, which also arise from intercostal and lumbar arteries but are shorter and smaller than the anterior medullary arteries [4, 18]. All spinal cord feeders are functional end arteries [18].

Clinical Background

The systemic circulation of the lung is the primary source of bleeding in hemoptysis [19]. This is known from angiographic studies and bronchoscopy, and from the finding that expectorated blood usually has an arterial saturation of oxygen. Chronic inflammatory diseases of the lung are the most common cause of hemoptysis [20]. Bronchopulmonary arterial shunts develop in peribronchial inflammatory tissue [10]. The resultant increase in flow leads to dilatation of the bronchial arteries. Hemoptysis occurs secondary to rupture of a bronchial artery or to diffuse oozing of blood across inflamed tissue. Tuberculosis is the most common in-

flammatory condition associated with hemoptysis, particularly when a cavitary lesion has been colonized by aspergillus [20]. Bronchiectasis, pneumoconiosis, and cystic fibrosis are also associated with hemoptysis [2]. Bronchogenic carcinomas can erode into a bronchial artery with subsequent hemoptysis.

The pulmonary circulation may be the source of bleeding in the occasional patient with hemoptysis [21]. In this situation, bleeding usually occurs from rupture of a pulmonary artery aneurysm or arteriovenous fistula. Most pulmonary artery aneurysms are caused by infection, although some are congenital and some are due to a vasculopathy [22]. Mycotic aneurysms can develop in acute necrotizing pneumonia, bacterial endocarditis, and syphillis [23], but the most common source of bleeding from the pulmonary circulation is a Rasmussen aneurysm. This is a pseudoaneurysm that develops when there is erosion of a peripheral pulmonary artery into a tuberculous cavity [24].

Most episodes of hemoptysis are small in volume and stop with bedrest, postural pulmonary drainage, and supportive therapy [25]. However, when hemoptysis is massive and unremitting there is a high mortality from asphyxiation or exsanguination. The clinical work-up includes a chest X-ray film, a coagulation profile, and bronchoscopy in an attempt to localize the bleeding site. Angiography has been used to identify the site of bleeding but is frequently ineffective [26]. In the past, resection of the involved lobe was considered the standard therapy unless a contraindication to surgery existed [3], such as failure to identify the bleeding site, inadequate vital capacity to tolerate a lobectomy, nonresectable carcinoma, bilateral advanced pulmonary disease, or recurrent hemoptysis following lobectomy. In these situations bronchial artery embolization was recommended.

Today, embolization is increasingly viewed as a primary form of treatment for massive or recurrent hemoptysis [1, 2], even in patients with no contraindication to surgery [1]. Massive hemoptysis is defined as the expectoration of at least 300 ml of blood in 24 h [22]. A single episode of hemoptysis carries the risk of asphyxiation if it approaches the volume of the tracheobronchial tree (approximately 150 ml). Recurrent episodes of hemoptysis which require transfusions to maintain the patients hematocrit also warrant bronchial artery embolization [1].

Technique

Bronchial artery embolization should be performed as soon as possible after the onset of massive hemoptysis. It should be understood that these patients usually have advanced chronic lung disease and may be unable to maintain the supine position. The procedure can be performed with the patient reclining, with periodic breaks as needed to permit clearing of blood from the bronchi. Oxygen must be available and some patients will require selective intubation of the uninvolved bronchus to maintain an adequate airway.

A neurological exam should be performed before attempting bronchial artery embolization. During the course of the procedure, the patient must be closely observed for myotonic jerking of the lower extremities, and frequent checks must be made of motor and sensory function. Moderate sedation may be used to reduce anxiety and discomfort but should not impair the patient's ability to cooperate and communicate. It has been suggested that somatosensory-evoked potentials provide the most sensitive method of assessing the potential for spinal cord complications [27]. This technique monitors nerve conduction through the spinal cord and provides an early indication of ischemia. Additional experience will be needed before somatosensory-evoked potentials are routinely utilized during bronchial artery embolization.

Angiography is directed toward a systematic identification of the bronchial arteries. A diagnostic angiogram is performed on each bronchial artery as it is located to determine its potential as the source of hemoptysis and to identify any spinal cord feeding vessels. Extravasation of contrast is rarely seen, even during episodes of massive hemoptysis [28]. Bronchial arteries are normally about 3.0 mm in diameter [4]; enlargement of the vessel or systemic-to-pulmonic shunting are the most reliable indications that the artery is abnormal and a potential source of hemoptysis (Fig. 3). Other localizing features include regions of hypervascularity and bronchial artery aneurysms [1, 28, 29]. Visualization of a posterior radicular artery is a relative contraindication that should provoke caution [1].

A Cobra, shepherd's crook, or Mikahelson-shaped catheter, with its tip tapered to 5.0 fr, is suitable for bronchial artery catheterization. The chosen catheter is passed into the descending thoracic aorta using the Seldinger transfemoral technique. The tip is advanced to just below the level of the aortic arch and directed antero-medially to search for the right intercostobronchial trunk; this vessel is the most likely to supply spinal cord feeders [4]. Care must be taken to avoid wedging the catheter, as this can result in spinal cord ischemia. The risk of spinal cord injury can also be reduced by the use of low-osmolar contrast agents and by limiting the total amount of contrast that is injected [1,

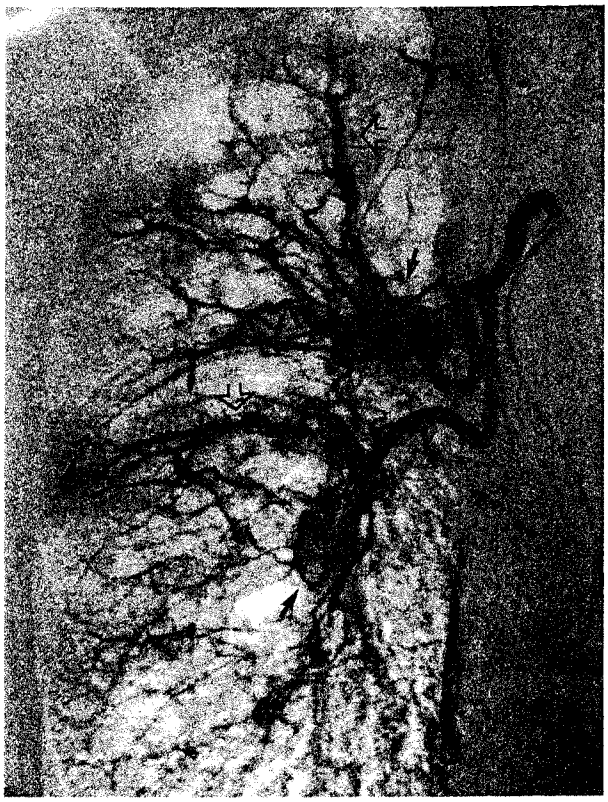

Fig. 3. Right bronchial arteriogram demonstrates vessel hypertrophy, areas of increased vascularity (small arrows), and systemic-to-pulmonic shunting (open arrows).

13]; a hand injection of 6–10 ml is usually sufficient. This vessel should be embolized if determined to be abnormal and the anterior spinal artery is not visualized (Fig. 4).

After thorough evaluation of the right intercostobronchial trunk, the anterior surface of the descending thoracic aorta is probed from T_4 to T_8. Each bronchial artery is identified in succession and its potential as a source of hemoptysis is assessed. All vessels that may contribute to the bleeding should be embolized (Fig. 5). Bilateral subclavian angiograms can be performed to locate bronchial arteries with aberrant origins and to identify any transpleural collaterals that might arise from branches of the subclavian and axillary arteries [30, 31]. Finally, a thoracic aortogram may be performed to confirm embolization of all the abnormal systemic arterial supply to the lung. When there is lower lobe disease, the aortogram should include the diaphragms to check for a contribution from the phrenic arteries.

The pulmonary circulation needs to be evaluated in cases where no feeding artery is identified or if bleeding persists after embolization of all suspicious systemic vessels supplying the lung [22]. Selective pulmonary arteriography should be performed on the side indicated by bronchoscopy. Pulmonary artery aneurysms and arteriovenous fistulae are the probable sources of hemoptysis when bleeding originates from the pulmonary artery.

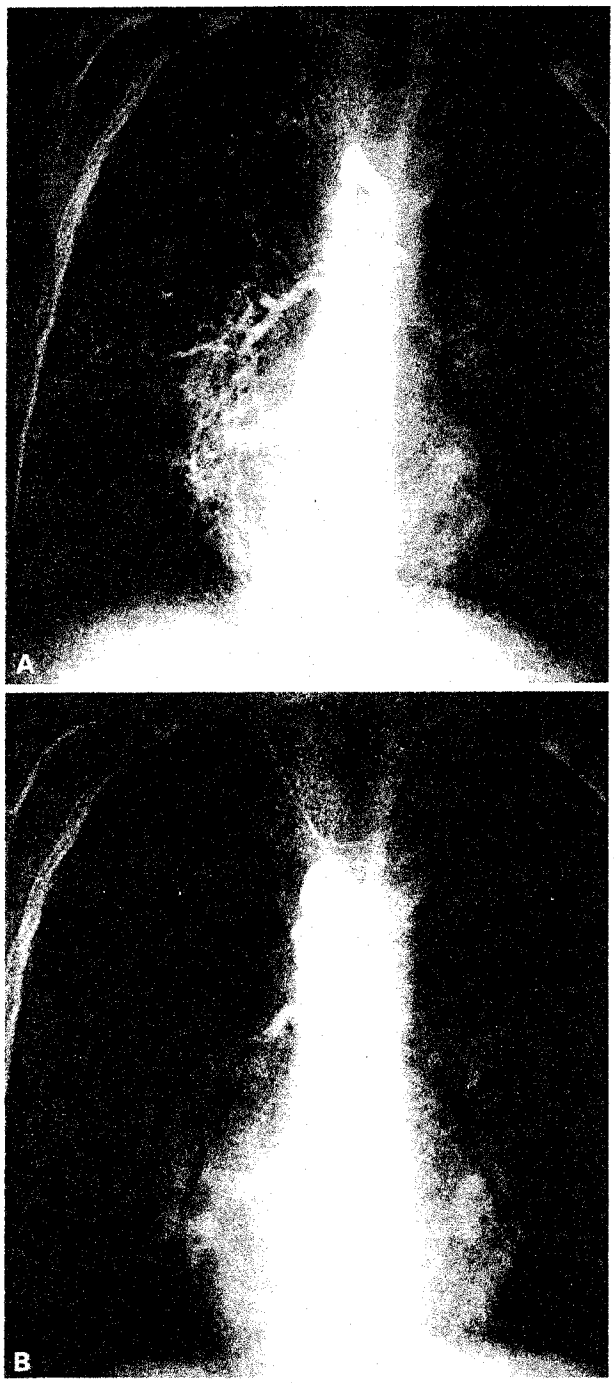

Fig. 4. **A** Angiogram of the right intercostobronchial trunk in a 7-year-old boy with cystic fibrosis and massive hemoptysis. Findings include vessel hypertrophy, regions of hypervascularity, and systemic-to-pulmonic shunting. **B** Repeat bronchial arteriogram, obtained after embolization with approximately 50 Gelfoam pledglets, demonstrates stasis of flow as well as occlusion of the peripheral branches. Note that the proximal vessel remains patent.

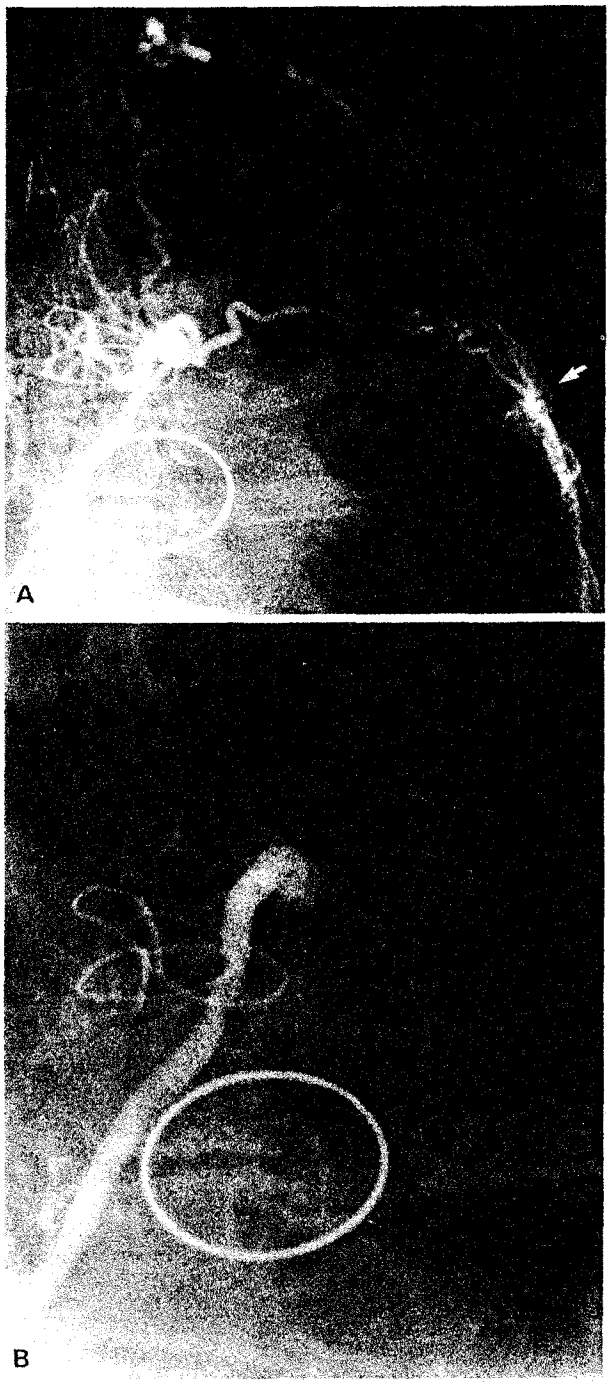

Fig. 5. **A** Angiogram of a bronchointercostal artery in a 19-year-old girl who developed massive hemoptysis after surgical repair of tetralogy of Fallot. An intercostal vessel supplies transpleural collaterals (arrow). **B** Repeat arteriogram obtained after embolization with Gelfoam pledglets, demonstrates occlusion of intercostal and mediastinal vessels.

These can be embolized using detachable balloons or steel coils [23, 24].

A number of agents are available for bronchial artery embolization. Surgical gelatin sponge (Gelfoam) has been used in most cases described in the literature; Gelfoam is readily available and easy to use. It has the potential disadvantage of being resorbed by the body; this may not be clinically significant, but it has prompted some authors to propose the use of polyvinyl alcohol (Ivalon) [1], a nonresorbable particulate embolic material. In regard to other materials, Boushy et al. [32] have shown that bronchial necrosis developed in most dogs that were embolized with glass microspheres smaller than 200 μm in diameter. They postulated that blockage of the bronchopulmonary anastamoses occurred, thus depriving the capillary bed of nutrients. For this reason fine particulates, bucrylate, and ethanol should not be used for embolization. Indeed, a case of bronchial necrosis has been reported following embolizaiton with ethanol [33], and this agent is more likely than others to reach the spinal cord [34]. Coils have also been used to occlude bronchial arteries. These provide proximal occlusion, but the distal vessel is likely to be reconstituted by the extensive bronchial and mediastinal collateral circulation. In fact, coils prevent reaccess to the bronchial arteries by the angiographer and virtually exclude future attempts to embolize with particulates.

It is imperative that a stable catheter position be obtained prior to embolization. Every precaution should be taken to maintain sterility of the particles to be injected. When Gelfoam is used, the initial particles should be 1–2 mm in size; several may be loaded at a time into a tuberculin syringe and slowly injected to prevent reflux into the aorta. About 10–20 particles of this size are needed to block the distal branches of the bronchial artery, but often, more than 50 will be necessary. The proximal branches are then occluded with particles 3–4 mm in size. Frequent hand injections of contrast are performed to follow the extent of occlusion and the rate of blood flow. Embolization is complete (Fig. 4) when 95% of peripheral branches are occluded and antegrade flow is stopped [26]; this may require 20–100 particles. Under no circumstance should the bronchial artery be packed to its orifice, as this carries the risk of refluxing particles into the aorta.

Complications

Aside from the small risk posed by inadvertent reflux of particles into the aorta, the major concerns in bronchial artery embolization are bronchial necrosis and spinal cord injury. The most common complaints following embolization are transient chest pain and fever of a few days duration [26]. Fortunately, serious complications are uncommon when proper technique is observed.

The proximal bronchi have poor collateral circulation [4] and are at risk of infarction from bronchial

artery embolization. Two patients are reported to have developed bronchial necrosis after this procedure. The first, who was embolized with 5 mm particles of gelatin sponge, developed a small area of necrosis of his right main-stem bronchus which resolved in several weeks [19]. Infarction of the left main-stem bronchus occurred in the second patient, who died from massive hemoptysis after ethanol was used as the embolic agent [33]. Branches of the bronchial arteries supply a portion of the esophagus, and dysphagia is not uncommon following embolization [1, 35]. A case of bronchoesophageal fistula has also been reported [36], which occurred after embolization with particles of gelatin sponge.

Transverse myelitis, though rare, remains the most dreaded complication of bronchial artery embolization [37]. The majority of reported cases occurred during diagnostic studies performed prior to the days of embolization and were related to contrast toxicity [9, 13, 14]. The incidence has fallen markedly with improved technique and the use of low-osmolar contrast agents [20]. Spinal cord injury has not been reported during bronchial artery embolization, although spinal cord infarction did occur after embolization of an intercostal artery that supplied the lung through pleural adhesions [38]. Should transverse myelitis develop, there is usually at least partial return of function with time [13].

Results

Massive hemoptysis is a life-threatening event. The primary goal of bronchial artery embolization is the immediate control of bleeding which has been achieved in 75–90% of patients [1, 2, 19]. In addition to stemming the hemorrhage, embolization permits early resumption of chest physical therapy which is needed by patients with advanced chronic lung disease [26].

Of the 10–25% of embolization attempts that fail to control hemorrhage, some are due to the death of the patient, from asphyxiation or exsanguination, prior to completion of the procedure. Other failures are technical in nature and include failure to identify and embolize all of the involved bronchial arteries, inability to obtain a sufficiently stable catheter position to allow embolization, and failure to embolize all of the chest wall collaterals that contribute to the hemoptysis [2, 31].

Of the patients successfully embolized, whether for massive or recurrent hemoptysis, about 20% rebleed within 6 months [1, 2, 19]. The majority of patients remain free of significant hemoptysis, although occasional blood-streaked sputum may persist. Rebleeding usually occurs because of incomplete embolization, recanalization of a previously embolized vessel, or hypertrophy of small collateral vessels that were not embolized initially [2]. Rebleeding is more common with aspergillomas in upper lobe cavities since these tend to recruit extensive chest wall collaterals through pleural adhesions [19]. In patients with lung cancer, ongoing invasion and necrosis may also cause rebleeding [22]. Bronchial artery embolization can be successfully repeated in patients who rebleed.

Conclusion

Massive hemoptysis is an uncommon but life-threatening complication of chronic inflammatory lung disease and bronchial neoplasms. The systemic circulation of the lung is the source of hemoptysis in almost all patients. Bronchial arteries are readily embolized with Gelfoam or Ivalon. Hemorrhage is controlled by this method in at least 75% of patients, with only a 20% recurrence rate during the first 6 months. The potential complications of bronchial necrosis and spinal cord infarction are rare when established techniques are utilized.

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