EMBOLIZATION OF BRONCHIAL ARTERIES FOR THE TREATMENT OF HEMOPTYSIS. Update and literature review.

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Summary: Massive hemoptysis is an emergency. It was formerly assessed by means of chest X-Ray, fibrobronchoscopy and CT. In the last few years multislice tomography has achieved good results in localization of the hemorrhage and in the identification of arterial anatomy.

The embolization of bronchial arteries and non-bronchial systemic arteries, a minimally invasive technique, is a safe and effective treatment. This article reviews and updates this technique.

Key words: Hemoptysis, Arterial Embolization, Interventional Vascular Radiology

1-Introduction.

Hemoptysis is a life-threatening emergency requiring prompt diagnosis and treatment.

Conservative medical treatment of massive hemoptysis used to consist in local and peripheral vasopressin infusion, and such local measures as bronchial instillation of vasopressin, balloon obstruction of the involved bronchus or selective intubation of the non-involved lung so that it would not be inundated with blood (1-3). This treatment had a morbimortality of around 50% (4).

Surgical treatment, if performed at the acute stage, also shows bad results, morbimortality being very high. It consists in total or segmentary lobectomy if the lesion is identified and localized (1-2). Percentages of mortality in elective surgery were about 18% and around 40% for emergency surgery.

In this context the embolization of bronchial arteries, pioneered by Remy in 1974 in France and published internationally 3 years later (5) appeared as a minimally invasive but highly effective treatment for immediate control of bleeding. It has become established as the method of choice for the treatment of massive hemoptysis ever since (6).
For this study we reviewed the technique, its indications, its restrictions and its complications, its early and long-term outcomes. We also reviewed special situations that can arise in clinical practice.

2-Pathophysicsiology and etiology of hemoptysis.

Arterial pulmonary circulation is dual: pulmonary arteries plus bronchial arteries. (2)

Pulmonary arteries provide 99% of the arterial supply and are responsible for gas exchange.

Bronchial arteries, which provide only 1% of arterial supply, operate as nutrient vessels for the walls of the tracheobronchial tree and as vasa vasorum for pulmonary arteries and pulmonary veins; they also provide small bronchopulmonary branches for lung parenchyma.

Both systems, the pulmonary arterial system and the bronchial arterial system, intercommunicate by small anastomoses at bronchial and parenchymal level, which constitute a physiological right-left shunt.

This circulation is observed in the respiratory system under completely normal conditions.

No other arterial vessels are involved in pulmonary circulation under normal conditions.

In pathological situations we shall review later on there may be other systemic branches involved (the internal mammary arteries, for example), which may originate hemoptysis.

Pulmonary circulation may be compromised in several conditions leading to vasoconstriction on account of hypoxia, vasculitis and thrombosis. In those circumstances bronchial arteries enlarge gradually and replace the main blood supply either at the lesion or throughout the lung. This chronic inflammation not only enlarges the bronchial arteries: concomitantly arteriovenous shunts between both circuits enlarge as well. In those circumstances inflammation mediators and angiogenetic growth mediators are released; neovascularization appears with engagement of systemic vessels that commonly are not included in the arterial supply to the lung (3).

These new vessels have thin walls, where aneurysms and pseudoaneurysms develop. Exposure to systemic pressure and inflammation further weaken their thin walls and bring about their rupture. This is followed by blood extravasation into the airways, which produces what is known as hemoptysis (2-3).

Numerous conditions can lead to this process; the most frequent ones include bronchiectases, tuberculous cavities, aspergillomas, pyogenic abscesses and tumors. Rasmussen’s aneurysms, caused by erosion of pulmonary arteries, may originate a small percentage of hemoptysis (10%) and may even be visualized angiographically, by the opacification of bronchial arteries or systemic arteries (intercostal or vertebral) on account of the abnormal communication between both systems in
the aforementioned conditions. (Figure 1)

3-Massive hemoptysis: definition

The interventional radiologist must know not only the technique to be performed in order to stop a hemoptysis, he must also have a clear knowledge of this symptom, its severity, its possible causes and the assessment to be done before angiography and embolization are performed. He must also have a clear idea of risks, benefits, indication and timing of this procedure. It is likewise important to stress that we are a multidisciplinary team where every step of diagnosis, treatment and follow-up of the patient must be discussed first.

On account of the aforementioned it becomes necessary to revise some clinical concepts.

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**Fig. 1-**
Secuelar Aspergiloma Cavern. HIV 36 old patient. Severe hemoptis in the last 24 hours.

- a) Thorax radiography shows a secuelar cavity in the left pulmonary apex.
- b y c) Aortography in early and late phase shows a pathological circulation in the periphery of the cavern. An arteriovenous shunt is observed with left pulmonary vein opacification.
- d) Selective catheterization of the left internal mammary artery shows the anomalous vascularization in the periphery of the cavern. A nodular image compatible with a Rasmussen aneurysm is observed.
- e) Post embolization result with 300-500 and 700-900 micres of tryacaryl.
Hemoptysis is defined as the expulsion of blood from the part of the respiratory tract that lies under the glottis.

According to expectorated volume hemoptysis falls into several categories: small quantities of expectorated blood, blood-streaked sputum, mild hemoptysis when the volume is less than 150cc in 24 hours, moderate or severe when it amounts to 150-500cc a day, and massive when it exceeds 600cc a day. This classification is not always useful in clinical practice; it has been questioned by some authors and need not be taken into account before embolization if the indication has been discussed by the multidisciplinary group (3).

In many cases embolization is the first therapeutic procedure. It is intended as a palliative therapy, not as a curative treatment, and as such precedes surgery.

Our experience includes the embolization of patients with persistent blood-streaked sputum related to a neoplastic pulmonary nodule; although the daily volume of sputum was not considerable, persistency of the hemorrhage and a tendency to increase were viewed as a hemoptysis threat.

Therapeutic decision must be taken by a multidisciplinary team whose members must always keep in mind that hemoptysis is life-threatening on account of the functional compromise of the airway and not because of hypovolemia (2).

Studies in hemoptysis patients must aim at a quick localization of the hemorrhage site and if possible, the etiology of this hemorrhage. It is important to know whether the patient is taking anticoagulants and to confirm it as soon as possible by means of coagulation studies. At the same time other studies must be undertaken to determine the site and the etiology of the hemorrhage. The site or the region must be identified as accurately as possible, and it must be determined, if at all possible, if the condition is one-sided (a residual tuberculous cavity or a tumor, for example) or if it is bilateral and widespread as is the case with bronchiectases.

Three studies are available for the determination of the hemorrhage site: plain chest X-ray, fibrobronchoscopy and computed tomography (7-10).

The last few years have brought an addition to this group: multidetector computed tomographic angiography (11) whose role and results more will be mentioned in the next item.

In emergency situations plain chest X-ray is a low yield study that contributes diagnostic data only in 50% of the cases (7, 8). These findings may be tumors, cavities, images compatible with bronchiectases.

A few years ago fibrobronchoscopy was the first study to be performed (1-2). Its role exceeds the scope of this review, we will merely point out that nowadays its use has become controversial and some reviews state that it may be unnecessary when lesions have been well localized by imaging studies (9). Some studies have
demonstrated that fibrobronchoscopy, if performed at an early stage, indicates the hemorrhage site in 91% of the cases, while in the case of ongoing hemorrhage of some duration, according to other authors, it contributed to diagnosis only in 3 out of 29 cases (10). A recently published study (11) shows that visualization of active hemorrhage was achieved in 84.2% out of 111 patients while in the same series visualization after cessation of hemorrhage was possible only in 19.1%.

Both CT and the aforementioned multislice CT contribute a wealth of localization and etiology data.

Computed tomography can contribute important information for the localization of hemorrhage, it can even localize it by itself in 63%-100% of the cases (7). The percentage may be higher if CT is combined with fibrobronchoscopy. The combination of fibrobronchoscopy and CT is the most effective algorithm to use for a first assessment (8).

It should be clearly understood that bronchoscopy and CT do not compete, they are complementary. If we had to choose between them, we would opt for CT because we think it is the most useful one, as Galli E et al have affirmed (9).

<table>
<thead>
<tr>
<th>Author</th>
<th>Date</th>
<th>Number of patients</th>
<th>Immediate control</th>
<th>Recurrences (30 days)</th>
<th>Long-term recurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remy</td>
<td>1977</td>
<td>49</td>
<td>41 (84%)</td>
<td>14 (28,6)</td>
<td>28,6%</td>
</tr>
<tr>
<td>Uflaker</td>
<td>1985</td>
<td>75</td>
<td>49 (76,6%)</td>
<td>No data</td>
<td>21,4%</td>
</tr>
<tr>
<td>Rabkin</td>
<td>1987</td>
<td>306</td>
<td>278 (90,8%)</td>
<td>39 (12,75%)</td>
<td>36 (12%)</td>
</tr>
<tr>
<td>Hayakawa</td>
<td>1992</td>
<td>58</td>
<td>50 (86,2%)</td>
<td>14 (28%)</td>
<td>28%</td>
</tr>
<tr>
<td>Ramakantan</td>
<td>1996</td>
<td>140</td>
<td>102 (73%)</td>
<td>38 (27,1%)</td>
<td>No data</td>
</tr>
<tr>
<td>Mal</td>
<td>1999</td>
<td>56</td>
<td>43 (77%)</td>
<td>7 (12,5%)</td>
<td>31 (55%)</td>
</tr>
<tr>
<td>Swanson</td>
<td>2002</td>
<td>54</td>
<td>51 (94%)</td>
<td>13 (24,1%)</td>
<td>No data</td>
</tr>
<tr>
<td>De Gregorio</td>
<td>2006</td>
<td>287</td>
<td>256 (91,1%)</td>
<td>25 (8,8%)</td>
<td>45 (22,3%)</td>
</tr>
<tr>
<td>Poyanji</td>
<td>2007</td>
<td>140</td>
<td>138 (98,5%)</td>
<td>14 (10%)</td>
<td>14 (10%)</td>
</tr>
<tr>
<td>Lee</td>
<td>2008</td>
<td>70</td>
<td>69 (99%)</td>
<td>No data</td>
<td>25 (26%)</td>
</tr>
<tr>
<td>Chun</td>
<td>2009</td>
<td>50</td>
<td>43 (86%)</td>
<td>No data</td>
<td>14 (28%)</td>
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<tr>
<td>Yoo</td>
<td>2011</td>
<td>108</td>
<td>105 (97,2%)</td>
<td>7 (6,5%)</td>
<td>21 (20%)</td>
</tr>
<tr>
<td>Cornalba</td>
<td>2012</td>
<td>477</td>
<td>458 (96%)</td>
<td>No data</td>
<td>121 (25,36%)</td>
</tr>
<tr>
<td>Hwang</td>
<td>2013</td>
<td>72</td>
<td>67 (93,1%)</td>
<td>13 (18,1%)</td>
<td>29 (40,3%)</td>
</tr>
</tbody>
</table>

TABLE 1
Comparison of the main series published in the period 1977 - 2013
Anyway this depends on the clinical status of the patient, it should not be forgotten that hemoptysis patients die because of airway compromise, not on account of hypovolemia; this must be remembered if aspiration becomes necessary.

No bronchial artery embolization should be undertaken without the orientation of previous studies, otherwise treatment will be more difficult (8, 9).

4ª- Multislice computed tomographic angiography for the study of bronchial arteries (12-14)

Angiotomography with 16-detector multislice equipment has proved to be quite effective for the identification of bronchial and non-bronchial arteries in cases of hemoptysis (12); in a comparative retrospective study of conventional angiography and angio CT an agreement of 86% was observed regarding their identification. Recently published prospective studies (14) have demonstrated that angio CT identified 100% of the arteries causing hemoptysis (which were embolized); the same study reports that 2 hypertrophic non-bronchial arteries were identified in CT and not during the arteriography that was performed later.

This technique allows simultaneous study of both arterial circuits and therefore the identification of bronchial arteries as the cause of bleeding, the involvement of systemic non-bronchial arteries and also the participation of pulmonary arteries including Rasmussen’s aneurysms related to tuberculous cavities and involvement of pulmonary arteries with tumors (12, 13 and 14). These aneurysms may be evidenced by catheterization of bronchial or systemic arteries, because arterial shunts between both systems hypertrophy in pathological situations (15).

4b-Angiographic study of pulmonary arteries

In a minor percentage of patients, hemoptysis may originate in the pulmonary arteries. In such cases, bleeding begins as a result of eroded pseudoaneurysms associated with aspergillomas, tuberculous cavities or pyogenic abscesses (10, 15-17).

Plain chest X-ray usually shows suggestive findings such as necrotic cavities or cavitary lesions near the central pulmonary artery (Figure 1a) (10).

In 1984 Remy et al (15) published a series of 72 patients. Six of them had recurrent bleeding; the findings were eroded pseudoaneurysms in five cases, aspergilloma in one case, tuberculous cavities in two cases and pyogenic abscesses in two cases.

Further on, in 1987, Rabkin (16) published one of the most numerous series; it included 306 patients who underwent embolization of bronchial arteries. In 93% (26/28) of the patients whose hemorrhage did not cease immediately, the cause was found to be a lesion of the pulmonary artery. More recently published series have found up to 10% of cases (8/76) with bleeding...
secondary to pulmonary pseudoaneurysms (7, 16) (Table 1).

Another known cause of pulmonary artery hemorrhage, albeit infrequent, is arteriovenous malformation, which can be treated successfully with coils (16).

The conclusion of all the above findings is as follows: pulmonary arteries must be examined whenever the study of bronchial arteries did not find the cause of hemoptysis and also in those patients who present with recurrent hemoptysis (7).

5 – Anatomy of the bronchial arteries

It is essential to know the anatomy of the bronchial arteries in order to achieve adequate embolization in hemoptysis patients.

Bronchial arteries are subject to great anatomical variation regarding origin, number, and route. They originate directly from the anterolateral surface of the descending aorta at T5-T6 level.

Several classifications are available:

Caudwell reports 4 classic patterns for bronchial arteries, which are perhaps the most accepted ones. Some authors describe more, up to 10 patterns.

We will describe in this study the three classifications outlined in Uflaker’s Atlas of Angiographic Anatomy (15): Cauldwell’s classification, Botenga’s and Uflaker’s own (18).

a) Cauldwell’s classification (7, 8, 9, 10 and 18): This author uses only 4 groups because he considers they include 90% of all possible anatomical variants. That leaves 10% of variants outside this classification.

Type 1- Two bronchial arteries on the left and one intercostobronchial trunk on the right (40.6%).

Type 2- A single bronchial artery on the left and one intercostobronchial trunk on the right (21.3%).

Type 3- Two bronchial arteries on the left and two on the right, one of them being an intercostobronchial trunk (20.6%).

Type 4- A single bronchial artery on the left and two on the right, one of them presenting as intercostobronchial trunk (9.7%).

This classification omits to mention the case of both bronchial arteries originating in a common trunk.

b) Botenga’s classification (18)

Botenga proposes, like Uflaker, 10 different pattern types.

Type 1- Two bronchial arteries on the left and one intercostobronchial trunk on the right (27.7%).

Type 2- A single bronchial artery on the left and one intercostobronchial trunk on the right (17.0%).

Type 3- A single bronchial artery on the left, one intercostobronchial trunk on the right and a common trunk as the origin of a single right bronchial artery and a single left one (17.0%).

Type 4 – Two bronchial arteries on the left, one intercostobronchial trunk and a
single bronchial artery on the right (10.7 %).

Type 5- Two bronchial arteries on the right and a single bronchial artery on the left (8.5 %).

Type 6- Intercostobronchial trunk on the right and a common trunk from which arise both right and left bronchial arteries (8.5%).

Type 7- Common bronchial trunk (4.3%).

Type 8- Intercostobronchial trunk and single bronchial artery on the right, three bronchial arteries on the left (2.1 %).

Type 9- Intercostobronchial trunk and two bronchial arteries on the right and a single bronchial artery on the left (2.1%).

Type 10- A common bronchial trunk with one right bronchial artery and one left bronchial artery, and a single left bronchial artery (2.1%).

c) Uflaker’s classification (6,18)

Pattern 1- A single bronchial artery on the left and an intercostobronchial trunk on the right (30.5%).

Pattern 2- One intercostobronchial trunk on the right and a common trunk from which arise both right and left bronchial arteries (25.0 %).

Pattern 3- Two left bronchial arteries and one intercostobronchial trunk on the right (12.5%).

Pattern 4- Right intercostobronchial trunk, single right bronchial artery and single left bronchial artery (11%).

Pattern 5- A single left bronchial artery, an intercostobronchial trunk on the right and a common trunk from which arise one right bronchial artery and one left bronchial artery (8.3%).

Pattern 6- Right intercostobronchial trunk, single left bronchial artery and a common trunk in caudal position (4.2%).

Pattern 7- Common bronchial trunk (2.8%).

Pattern 8- Right intercostobronchial trunk from which arises one left bronchial artery, and another single bronchial artery on the left (2.8%).

Pattern 9- Two common trunks giving origin to bronchial arteries on the right and on the left (1.4%).

Pattern 10- Right intercostobronchial trunk, single right bronchial artery and common trunk giving origin to a branch on each side (1.4%).

Some remarks should be added concerning this variety in classification:

Cauldwell’s classification, the oldest one, is the one most often mentioned in review studies (7-10). It was done in cadavers. It is perhaps the briefest one and therefore the most practical one but it does not take into account the existence of a single trunk giving origin to arteries for both sides, as we mentioned before.

When this common trunk gives origin to arteries on both sides, as will be illustrated with some examples below, it can make selective catheterization to both sides difficult on account of its brevity and direction. This increases the
probability of complications. The real prevalence of the common trunk is unknown (8).

A right intercostobronchial trunk is quite frequent, in our experience it is one of the most frequently embolized vessels, perhaps on account of right apex lesions being so frequent.

Bronchial arteries provide blood supply to the trachea, to the airways within and without the pleura, to connective tissue, nerves, regional lymph nodes, visceral pleura and esophagus, and also to the vasa vasorum of aorta, pulmonary artery and pulmonary veins (8).

Bronchial arteries originating above or below vertebral bodies T5-T6 are considered anomalous or ectopic. Some authors have reported their prevalence as ranging from 16.7 to 30% (7), others estimate prevalence in a range of 8.3% to 35% (8). They arise from very different sites, such as the aortic arch, the internal mammary artery, the subclavian artery, the costocervical trunk, the inferior phrenic artery and the abdominal aorta. Anomalous or ectopic bronchial arteries must be distinguished from non-bronchial systemic arteries, bearing in mind that bronchial arteries follow the bronchi along their whole course. Most of the ectopic bronchial arteries originate from the aortic arch. The percentage of ectopic bronchial arteries originating elsewhere is unknown (8).

This variety in anatomical origin makes it evident that embolization should be performed with care and perseverance in order to be complete and avoid recurrences.

Non-bronchial systemic arteries—Chronic inflammatory processes tend to recruit vessels from the systemic circuit transpleurally. These vessels have been noted to originate from very diverse sites: subclavian arteries, internal mammary arteries, thyrocervical trunk, phrenic arteries and intercostal arteries. They characteristically do not run parallel to the bronchi. The radiologist must look for them systematically in order to avoid recurrences. They can be localized with angio CT (12) and panoramic aortography, the latter being performed during the interventional procedure (Figure 1b,c) (7,8).

Artery of Adamkiewicz—During the catheterization of intercostal arteries and bronchial arteries the radiologist may see the arteries supplying the spinal cord, which deserve careful attention. These are the two posterior spinal arteries, which are parasagittal, and the anterior spinal artery, known as arteria radicularis magna of Adamkiewicz, a single median artery originating from intercostal branches. The artery of Adamkiewicz generally begins between T9 and T12 (8) but variations occur. Sometimes it has a higher origin, at T4-T12 level and sometimes it arises from a right intercostobronchial trunk, in this latter situation it can be identified on account of the classic hairpin shape of its upper end and occluding it must be avoided.
6-Technique of bronchial embolization (Figures 2 and 3)

a) Catheterization and semiology of pathologic arteries.

Embolization of bronchial arteries begins with a diagnostic angiography performed by means of arterial puncture according to the Seldinger technique. Most of bronchial angiographies are performed by catheterization of the punctured femoral artery. If this access proves difficult in the patient, one can decide to puncture the humeral artery; in this case the left humeral artery is the more practical option since it provides a very comfortable access for catheterizing the bronchial arteries and their embolization.

Once the arterial puncture has been done according to the Seldinger technique, an arterial 5 F sheath is placed and a 5F or 6F multifenestrated pigtail catheter is advanced up to T5 level in order to perform a panoramic aortography with a volume of 40cc and a flow of 25cc per second.

The embolization procedure for hemoptysis patients begins with a diagnostic panoramic aortography aiming at the visualization of bronchial arteries and non-systemic circulation involved in the pathological process.
This first arteriography often allows visualization of pathological arteries which are to be catheterized in a selective or a superselective manner. But in many cases it turns out to be negative.

Normal bronchial arteries measure less than 1.5 mm in diameter at their point of origin, that it is why not infrequently they go unseen in a panoramic arteriography or cannot be selectively catheterized with a 5F catheter (1.6 mm). Arteries are considered hypertrophic if their diameter exceeds 2mm (4-8).

Pathological lung areas can also be visualized, depending on the severity of vascular alterations.

The pigtail catheter is removed and selective catheterization, both of bronchial arteries and systemic non-bronchial arteries that are seen as altered, gets under way (Figure 2).

Preferred catheters for selective bronchial arteriography are Cobra, Simmons’s and Mikaelson’s, but other catheters can also prove useful, like the internal mammary catheter and the multipurpose catheter, for example (6).

The equipment of choice is a digital one, because it enables to reach complete high-quality diagnoses and to decrease the quantity of contrast agent.

It is very rare to visualize extravasated contrast as a direct sign of bleeding. Therefore attention should focus on other semiologic elements, in order to find out which pathological vessels are to be embolized.

Those signs are the following (6-10): -Hypertrophy of bronchial arteries; their diameter will exceed 2mm, thus which makes possible to catheterize them with 5F catheters (Figure 3 y Figure 4).

-Hypervascularity (Figure 2a)

-Systemic-pulmonary fistulae (Figure 1c).

-Aneurysms or pseudoaneurysms (Figure 1d).

Selective catheterization, which permits proximal access to the ostium of the vessel, is linked to increased reflux during embolization and also to increased risk of complications resulting from embolization of non-targeted territories.

During the last few years superselective catheterization has been increasingly employed (19-20). The procedure consists of inserting a coaxial micro catheter into the 5F catheter and then advancing it as far as possible towards the embolization target by means of a micro guidewire. In this way the possibilities for complications would diminish, as will be discussed further on.

When performing a superselective catheterization (19-20) the ratio of the micro catheter lumen to the size of the embolizing particles must be considered. A lumen of 0.021 or 0.027 is recommended for use, which does not set any limits to the size of macro particles (9).

Having reached a diagnosis, treatment will follow, in the shape of arterial embolization of affected areas, that is to say, of pathological arteries. We have
different materials for embolization at our disposal, and we must know the characteristics of each of them.

**b) Embolization materials**

The most frequently used materials are embolizable particles: Gelfoam, polyvinyl alcohol (known as PVA), calibrated Trisacryl particles and occasionally glue-like elements like Histoacryl, and even coils or micro coils (4).

Characteristics, indications and limitations of each material are analyzed below.

**Gelfoam** or “Espongostan” is well-known: a widely available hemostatic sponge used in surgery, it can be cut manually in small 1-mm squares, which are soaked in saline and contrast, inserted into a syringe and pushed into the 5F catheter. It was the first material to be used, on account of its being widely available and easy to manipulate, besides being low cost. Its greatest drawback is that the occlusion lasts only for a few weeks, about 20 days, which is why its use is not recommended.

Calibrated **polyvinyl alcohol (PVA) particles** are presented in vials; particle size ranges from 50 microns to 1000 microns. Particles in the 350-500 micron range and in the 500-700 one are used for the embolization of bronchial arteries. These non-absorbable particles are the most widely used material for embolization of bronchial and systemic arteries round the world for hemoptysis patients. Particles under 350 microns should not be used, because in that size range the risk of complications increases, and this applies in particular to occlusion of the arteria radicularis magna of Adamkiewicz. Particles are dissolved in a solution of non-ionic contrast and saline (50-50%) that must be constantly shaken. The solution is loaded in a 20cc syringe connected with a three-way luer lock and the volume to be embolized in injected slowly into 1cc syringes. The PVA is slowly injected under fluoroscopic control, watching closely to avoid reflux into the aorta (9). Washing the catheter or the micro catheter with saline is to be recommended, because PVA particles tend to clump and thus occlude the catheters, which in turn favors reflux (9).

**Calibrated particles of Trisacryl** (Embospheres) are a recent addition. These non-absorbable particles are perfectly calibrated to a uniform, regular shape. That would be their best asset because it would avoid obstruction of the catheter or the micro catheter during infusion. Trisacryl particles tend to clump less by comparison with PVA particles. In our experience the also tend to occlude more rapidly than PVA particles. That is why technique must be painstaking; 1cc syringes must be used and the injection must be pulsatile, watching for slowing of the circulation during embolization and progressive vessel occlusion. If injection is continued when flow has slowed down markedly, the risk of unseen reflux into the aorta increases (9).

**Absolute alcohol** cannot be recommended as an embolizing agent in this condition because it necrotizes the bronchial wall (10).
N-butyl cyanoacrylate (Histoacryl) combines with lipiodol to change its polymerization rate and its visibility. This glue-like material is particularly useful for high-flow fistulae that cannot be solved with particles, because they go through the shunt. Published animal studies (21) and recently published human studies concerning big populations (22, 23) both show that against former thinking no risk of tissue damage is involved and damage to lung parenchyma or mucosa is infrequent. Its use demands very skilled personnel. Although it is frequently used in Interventional Neuroradiology, its utilization in peripheral areas is rare. The main indications for the use of this material are pulmonary artery aneurysms and intended occlusion of internal mammary artery and branches of the subclavian artery, a territory where the use of particles is particularly risky on account of possible reflux into the vertebral artery (8).

Some recent articles (24) have shown the use of Onyx as embolizing agent in hemoptysis patients. This copolymer is mainly used in the treatment of intracranial arteriovenous malformations and dural fistulae. Its components are dimethyl sulfoxide (DMSO) and ethylene-vinyl alcohol (EVOH). The studies reporting use of this product are quite few. Use is reserved for cases where pulmonary artery embolization is required. We think this is not the ideal product for an emergency situation such as ongoing hemoptysis because use of Onyx is time-consuming and requires a very experienced operator.

Fibrillar coils, 0.035 in size, are not routinely used because they only permit a very proximal occlusion with the corresponding phenomena: development of collaterals and recurrence of the lesion. Micro coils to be used with 0.018 guidewire may be useful in fistulae patients undergoing superselective catheterization (20) with micro catheter, provided the micro coil is placed quite distally to the fistula. Although this resource is available, it is rarely needed and infrequently used. One of the
conditions that may require its use is cystic fibrosis, because it usually entails the development of very hypertrophic vessels and wide fistulae that cannot be effectively occluded by particles (Figure 2b) (10); in these cases the selected coil must be 15-25% greater in diameter than the vessel in order to avoid a backward movement of the coil after its detachment. Catheter position must be kept stable.

9-Results

Embolization of bronchial and non-bronchial systemic arteries is accepted as a first-line technique for the treatment of threatening or massive hemoptysis. It has proved to be quite effective from the very first studies that were reported by Remy.

The first series, including 49 patients, was reported internationally by Remy in 1977; success rate was 84% and recurrences amounted to 28.6%. Numerous series followed. Those publications are summarized in Table 1.

Those different series all demonstrate that bronchial artery embolization is a very effective procedure for the control of massive acute hemoptysis, with a success rate at the outset, that is, immediate control of hemorrhage, ranging between 73% and 98%.

Figure 3
Bronchiectasis
A) computed tomography: Bronchiectasis in right hemitorax. B and C) Rx thorax showing Bronchiectasis in a patient with Active hemoptysis of right bronchi. D and E) pre and post embolization arteriography of the inferior right bronchial artery, pathologic vessel occlusion with trysacryl particles.
The follow-up period ranges from 1 day to the first post-embolization month. The aforementioned table shows success rates and recurrence rates for different authors in the past 25 years. Reported recurrence rates are quite dissimilar, and the same applies to the follow-up periods. Some authors report immediate recurrence, while others report long-term follow-up starting three months after the procedure. On that account not all the series are comparable.

Recurrence rates, both on long- and medium-term, remain high, ranging from 10% to 55%. That is why, in spite of its effectiveness for the immediate control of hemorrhage, embolization is still considered in many cases a palliative treatment, aiming at stabilizing the patient with a view to elective surgery or pharmacological treatment. In many other cases it is the definitive treatment, according to the condition and the concomitant diseases of each individual patient (9).

Recurrences depend on several factors: the operator’s experience, the materials in use, the patient’s clinical condition.

Recurrent bleeding during the first days or weeks is considered due to incomplete vessel embolization or persistence of disease. It could also be due to revascularization of occluded vessels (if absorbable materials like Gelfoam were used) or to the development of collateral circulation by non-bronchial vessels (9). This latter instance is frequent in case of extensive pleural affection (9, 10). In such cases it becomes necessary to undertake a special examination of intercostal arteries and also of non-bronchial systemic collaterals like the internal mammary arteries and other branches of the subclavian arteries. If a tumor growth is involved, multiple pedicles supplying the tumor may have developed.

In most of the published series there is coincidence concerning illnesses and their incidence on recurrence. Bronchiectases and tuberculosis are the conditions that respond better to this treatment, while tumors usually have poor results (9).

Aspergilloma presents a high risk of recurrence because of its frequent association with Rasmussen’s aneurysm, which necessitates either pulmonary artery embolization or surgery. Remy was the first to report a case of Rasmussen’s aneurysm embolization in 1980; it concerned a residual tuberculous cavity with aspergilloma (25). Aneurysm visualization is often possible by means of reflux from bronchial arteries into the pulmonary artery through pathological shunts. As a rule, however, embolization of bronchial arteries is insufficient as definitive treatment for aneurysms and embolization of pulmonary arteries may prove necessary (16). Sbano reports a series comprising 66 patients in whom embolization of bronchial arteries was performed; during the 9-year follow-up period, 11% (8 cases) presented recurrences due to peripheral pulmonary aneurysms, which were treated with coils. In three cases the presence of aneurysms was linked to the existence of aspergilloma and in other two cases, to tuberculous cavities as a manifestation of reactivated disease. Rabakantan (26), who performed embolization of
In 140 tuberculosis patients, reports 73% effectiveness and considerable recurrence in the first 30 days. All cases were treated with espongostan, which explains these results. Poyanli (27), who treated a similar population using polyvinyl alcohol particles, reports better results with less recurrence. Recently Hwang (28) has recently published an analysis of risk factors for rebleeding in tuberculosis patients after embolization of bronchial arteries; he concluded that aspergilloma, diabetes mellitus and arteriovenous shunts are risk factors. In this series comprising 72 patients and including a retrospective analysis of risk factors immediate effectiveness amounted to 93.1% and overall recurrence after one year was 40.3% (Table 1).

Repeat embolization is more necessary in young patients with prolonged disease (10). This observation is especially true of cystic fibrosis patients in whom embolization of bronchial arteries has proven effective even if repeat embolization was required to achieve control. Brinson (28) achieves control in 15 patients out of 18 in his series in one session, but the remaining 3 patients required 3, 4 and 7 embolizations each. The causes for this high incidence of reembolization are the important development of non-bronchial circulation in this condition and the fact of the disease being bilateral. Cornalba (30) has recently published a review of his experience of 31 years; he observed a high incidence of cystic fibrosis (23%) in his population. This allows a comparison of recurrences in patients with this condition to patients otherwise afflicted. In patients with cystic fibrosis recurrence amounted to 38% (42/110), while in other conditions recurrence was observed in 21% (77/367) of cases.

As far as materials are concerned, recurrence is higher when absorbable materials like Gelfoam (10) are used. In the last few years N-butyl cyanoacrylate has been used, in vivo as well as in vitro, and it was proved that it produces no lesions in lung parenchyma. Yoo (23) published a numerous series comprising 108 cases in 2011, showing 97% effectiveness and 20% long-term recurrence during a 5-year follow-up. In this series aspergillomas have a high recurrence incidence, just as with other materials. The authors conclude that NBCA is a safe and effective means for the embolization of hemoptysis patients.

10-Complications of the procedure

The most dreaded complications of embolization of bronchial arteries are: post-embolization paraplegia due to a lesion of the arteria radicularis magna of Adamkiewicz and transverse myelitis linked to use of contrast. Although according to literature their incidence lies within the 1.4-6.5% range, it is more of a potential risk nowadays, an infrequent occurrence that can be minimized with the use of non-ionic contrast media, the right choice of particle size and a detailed arteriographic analysis in order to achieve adequate visualization of the artery, particularly when it originates from the right intercostobronchial trunk (4, 10).
The most frequent complication is transitory chest pain; prevalence ranges from 24% to 91% (8). Dysphagia secondary to embolization of esophageal branches is likewise a frequent complication and disappears spontaneously. Subintimal dissection, another frequent complication, is quite variable as to prevalence but usually causes no symptoms. Bronchoesophageal fistulae secondary to necrosis, embolization of peripheral organs as a consequence of reflux and transitory cortical blindness (due either to contrast or to embolism as an eventual consequence of shunts or reflux) have all been reported as less frequent complications (4, 8-10).

12. Conclusion

Embolization of bronchial and non-bronchial systemic arteries is a safe and effective method of treatment for threatening and massive hemoptysis. From the beginning it has shown a high level of efficacy regarding immediate hemorrhage control. Rates of long-term recurrence have decreased as the technique was perfected and new materials were developed. Complications can be minimized by a sound knowledge of anatomy, technique and currently available materials.

In order to optimize results it is important to assess the situation adequately with fibrobronchoscopy and/or computed tomography and angio CT before the procedure.

Indication has expanded, nowadays the method is not only indicated in severe or massive hemoptysis but also in moderate or chronic hemoptysis; it even extends to intermittent episodes (10).

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