41 Hemoptysis, Endoscopic Management

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Definition

Hemoptysis is defined as the expectoration of blood from the lower respiratory tract. Bleeding from the upper airway is excluded from this definition.

In most cases the amount of bleeding is slight, the patient has hemoptoic expectoration (blood-streaked sputum), and hemoptysis is self-limited. In other cases the amount is higher (evident hemoptysis) or may even present massive hemoptysis (expectoration of fresh blood in important quantities).

Massive hemoptysis usually refers to the expectoration of large amounts of blood and/or the rapidity of this bleeding and accounts for 20% of hemoptysis [1]. The amount of expectorated blood in 24 h is usually used to differentiate between massive and non-massive hemoptysis. However, this definition varies widely in the literature, with values ranging from an expectorated blood volume of 100–1000 mL during a period of time that is also variable. Difficulty is even higher considering that hemoptysis is difficult to quantify: it could be both overestimated and underestimated by patients. Underestimation may occur when part of the blood is retained in the tracheobronchial tree.

It is therefore preferable to use the term life-threatening hemoptysis, defined as that having clinical consequences, potentially fatal. This risk is determined by the total volume of bleeding, its velocity, and the patient's cardiopulmonary reserve [2]. As risk indicators, the amount of hemoptysis (greater than 100 mL), the presence of airway obstruction, respiratory failure, and hemodynamic instability should be considered [3]. Since 150 mL is the total volume of conduction airways, asphyxia due to clot formation along with cardiocirculatory collapse is usually the cause of death, not exsanguination. Mortality of untreated threatening hemoptysis is high, up to 80% with adequate management [4], so it is very important to have immediate assessment of the patient and identification of the causes of bleeding in order to start an appropriate treatment and avoid a fatal outcome.

Etiology of Hemoptysis

The causes of hemoptysis are multiple and varied.

Before detailing, it is important to know the system of vascularization of the lung.

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Vascular Origin of Hemoptysis

There are two systems by which blood reaches the lungs: pulmonary arteries and bronchial arteries. The pulmonary arteries conform to a low-pressure system that contains all cardiac output, and are responsible for gas exchange. The bronchial arteries (greater pressure and much lower flow) are part of the systemic circulation and the irrigation of the bronchi and the visceral pleura depends on them. Despite its lower contribution to pulmonary blood supply, the bronchial arteries are the source of most hemoptysis. Sometimes other systemic non-bronchial arteries may be the source of hemoptysis. In a much lower percentage, the bleeding comes from the pulmonary arteries or from the pulmonary microcirculation [5].

The vessels of the bronchial network causing bleeding are usually neoformed. Inflammation (bronchiectasis, sarcoidosis, lung abscess, tuberculosis, etc.), hypoxia, and neoplasia can induce proliferation of bronchial vasculature via pro-angiogenic factors (vascular endothelial growth factor, angiopoietin-1). Although new vessels are thin-walled and fragile, they are surrounded by smooth muscle fibers capable of contracting, both physically and pharmacologically. Arterial embolization is also an effective method to treat this neovascularization. However, the pulmonary artery network is not capable of generating a vasospasm as potent as the bronchial vessels, since its walls are thin and do not contract. Therefore, the physical and pharmacological means have only a slight effect on them. The most frequent cause of hemorrhage is ulceration of the vessel wall caused by a destructive process of the lung parenchyma (pulmonary neoplasia, bacterial necrotizing pneumonia, mycetoma). In these cases, the cessation of bleeding is usually due to the temporary sealing by a clot whose dissolution or progression of the tear can lead to a relapse with greater hemorrhage [6]. Unfortunately, it is not always feasible to differentiate the vascular network originating the hemorrhage (Table 41.1).

Table 41.1 Etiology of hemoptysis: Description of the most frequent causes of hemoptysis worldwide (the most important ones are underlined)

1. Pulmonary	
(a) Airways	• *Bronchiectasis* • *Bronchitis* • Fistula • Foreign body • *Neoplasm* • Trauma
(b) Parenchyma	• Infection – Abscess – *Mycetoma* – *Pneumonia* – *Tuberculosis* • Inflammatory or immunologic – Behçet's disease – Goodpasture syndrome – Granulomatosis with polyangiitis – Microscopic polyangiitis – Systemic lupus erythematosus
(c) Vascular	• Arteriovenous malformation • Dieulafoy's disease • Pulmonary artery pseudoaneurysm • *Pulmonary embolism* • Pulmonary veno-occlusive disease
2. Cardiovascular	• Congenital heart disease • *Heart failure* • Mitral stenosis
3. Iatrogenic	• Drugs – Antithrombotic drugs – Vascular endothelial derived growth factor inhibitor • Procedures – Transbronchial biopsy – Fine needle aspiration – Swan-Ganz catheter placement
4. Miscellaneous	• Coagulation disorders • Cocaine abuse • Endometriosis (catamenial hemoptysis)
5. Idiopathic	

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Multiple conditions may produce hemoptysis by affecting the airway, lung parenchyma, or pulmonary vessels. Although they vary according to the population studied, the most frequent causes are: tuberculosis (the leading cause of massive hemoptysis worldwide, [8] bronchiectasis, chronic bronchitis, and bronchogenic carcinoma [9]. A score has been developed to stratify the risk of mortality.

1. Pulmonary
   (a) Airways: Pathology of the airway is the most frequent cause of hemoptysis and includes:
      - Inflammatory diseases: bronchiectasis—frequently associated with moderate and severe bleeding—and chronic bronchitis.
      - Neoplasms: bronchogenic carcinoma, carcinoid tumor, and endobronchial metastasis. A European observational study showed that malignancy was the most frequent cause. Although up to 20% of bronchogenic cancer patients have some degree of hemoptysis, only 3% develop massive hemoptysis. [10]
      - Fistulas between the tracheobronchial tree and blood vessels, especially in the case of thoracic aorta aneurysms.
      - Foreign bodies and trauma.
   (b) Pulmonary parenchyma: Bleeding originating from the lung parenchyma is usually due to:
      - Infections: pneumonia (associated with mild expectoration), tuberculosis, lung abscess, and fungal infections, mainly aspergilloma.
      - Inflammatory or immunological diseases leading to diffuse alveolar hemorrhage: Goodpasture syndrome, systemic lupus erythematosus (SLE), granulomatous polyangiitis (Wegener), and microscopic polyarteritis.
   (c) Pulmonary vascular: Hemoptysis caused by diseases of the pulmonary arteries [9] may appear due to the same causes as those originating in the pulmonary parenchyma—intrinsic to the pulmonary vasculature conditions (pulmonary embolism, arteriovenous malformations).
      - Dieulafoy's disease of the bronchi (presence of an abnormal bronchial artery, contiguous to the bronchial mucosa) [11, 12].
2. Cardiovascular
   (a) Increased pulmonary capillary pressure (mitral stenosis).
3. Iatrogenic
   (a) Complications of procedure: transbronchial biopsy, pulmonary fine needle aspiration, artery perforation originated by a Swan-Ganz catheter placement [13].
   (b) Treatment with antithrombotic (antiplatelet or anticoagulant) drugs or bevacizumab (vascular endothelial derived growth factor inhibitor).
4. Miscellaneous
   (a) Coagulopathies: thrombocytopenia.
   (b) Cocaine inhalation.
   (c) Endometriosis: catamenial hemoptysis.
5. Idiopathic

   In up to 10–30% of cases it is not possible to establish an etiological diagnosis of hemoptysis following bronchoscopy and chest computed tomography (CT) [9, 14] and the patient is considered to have idiopathic or cryptogenic hemoptysis. Most of these patients are smokers and hemoptysis is usually due to inflammation of the bronchial wall produced by tobacco, rather than to an unspecified cause, known as tobacco-related hemoptysis [15]. Idiopathic hemoptysis is also related to chronic or acute bronchial inflammation, occult bronchiectasis, inactive tuberculosis, vascular pulmonary malformations, and coagulation disorders.

   It is likely that with the use of multidetector CT, the proportion of cryptogenic hemoptysis will be reduced [15].

History and Historical Perspective

Given its potentially fatal outcome, hemoptysis has been a challenge for physicians throughout the ages.

The first modern publications of cases of hemoptysis date back to the nineteenth century, in which the rupture of pulmonary artery aneurysms was described as a possible cause in patients with chronic pulmonary phthisis [16].

The predominant etiology has varied over the centuries, conditioned by toxic inhalation and environmental exposure, as well as by hygienic conditions and access to health care, which even today produce large regional variations.

Over time, treatments have changed from an initial systemic treatment (Gallic acid it the oldest publications) to the incorporation of both rigid and flexible bronchoscopy and the endobronchial use of different substances and devices, many of them without strong scientific evidence.

On the other hand, the generalization of CT and arteriography has significantly modified diagnostic and therapeutic management.

Recently in the context of the pandemic caused by Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) infection, few cases have been described in which hemoptysis was one of the initial manifestations [17].

Indications of Bronchoscopy in Hemoptysis

Bronchoscopy plays a key role in the diagnosis and management of hemoptysis, especially in those cases where the patient is too unstable for radiological tests and requires rapid intubation and in those cases where the origin of the bleeding is not identified by CT or arteriography. It allows confirmation in doubtful cases, location of the bleeding point or, at least, location of the affected lung, and the determination of the cause if the lesion is visible or accessible to endoscopic examination. It also allows the isolation of the hemorrhagic segment or lobe to avoid the spreading of blood to the bronchial tree and reduce the risk of suffocation. In this sense, performing rigid bronchoscopy complemented by flexible bronchoscopy carries a great advantage. In cases where a rigid bronchoscope is not at hand, flexible bronchoscopy as the only endoscopic procedure can also be very useful. It can be performed at the bedside and allows selective intubation or bronchial balloon blockade, as well as the application of local therapies. It can contribute, even temporarily, to control bleeding and the application of more definitive treatments such as embolization of bronchial arteries or even, in selected cases, surgical treatment.

Diagnostic Bronchoscopy

In the event of severe hemoptysis, diagnostic bronchoscopy can help in many ways:

1. Confirmation of hemoptysis and exclusion of pseudohemoptysis.

   Although the clinical history, the characteristics of the episode, and the initial physical examination may suggest the digestive or respiratory origin of the bleeding, sometimes the aspiration of at least part of digestive bleeding content causes cough and can simulate a true hemoptysis (pseudohemoptysis), which requires an ears, nose and throat (ENT) examination, a high digestive endoscopy, or bronchoscopy to differentiate.

2. Diagnostic of at least the side of bleeding, in anticipation of specific treatment.

   Although imaging studies (chest CT) can identify the origin of bleeding and its cause sometimes with a superior performance than bronchoscopy [7, 18], this is still necessary. It should be indicated early, especially in massive or life-threatening hemoptysis. Bronchoscopy reveals or confirms the origin of bleeding, especially if it is performed within 48 h of the onset of the episode and in cases of significant bleeding in 73–93% of cases of massive hemoptysis [7, 19]. A study comparing early bronchoscopy (active bleeding or within 48 h after bleeding stopped) to delayed bronchoscopy showed that an early procedure helps detect bleeding sources, especially in cases of moderate to severe hemoptysis without increasing diagnostic yield. [8]

   In the case of threatening hemoptysis, it is advisable to perform bronchoscopy as soon as possible if the patient is unstable and once the patient has been intubated [20, 21]. Endoscopy through the endotracheal (ET) tube is safer since the airway is secure and the endoscope can be withdrawn every time oxygenation worsens or the working channel is occluded by clots.

   Rigid bronchoscopy can be used for the diagnosis and initial evaluation of threatening hemoptysis, but the flexible bronchoscope has some advantages to it such as the ability to reach the distal airway more easily. It can be used in the setting more suitable for the patient—intensive care unit (ICU), shock room, bronchoscopy room, etc.—without the additional delays of having to transfer the patient to the operating room (OR) to undergo rigid bronchoscopy, or the radiology room to perform angiotomography.

Bronchoscopy also proves its value in those cases of non-revealing radiological studies or those that show bilateral or non-localizing abnormalities. In any case, even in those non-threatening episodes, it provides useful information in the event that bleeding increases dangerously in a sudden and unpredictable manner.

Location of the bleeding site requires direct visualization of active bleeding, which determines with certainty one bronchus or the responsible bronchial area. The most frequent endoscopic finding is hematic remains and clots (Fig. 41.1). Locating blood clots does not guarantee the origin of the bleeding. However, a combination of findings such as a great number of clots adhering to a particular bronchus can suggest, together with the imaging techniques, the responsible area. Blood

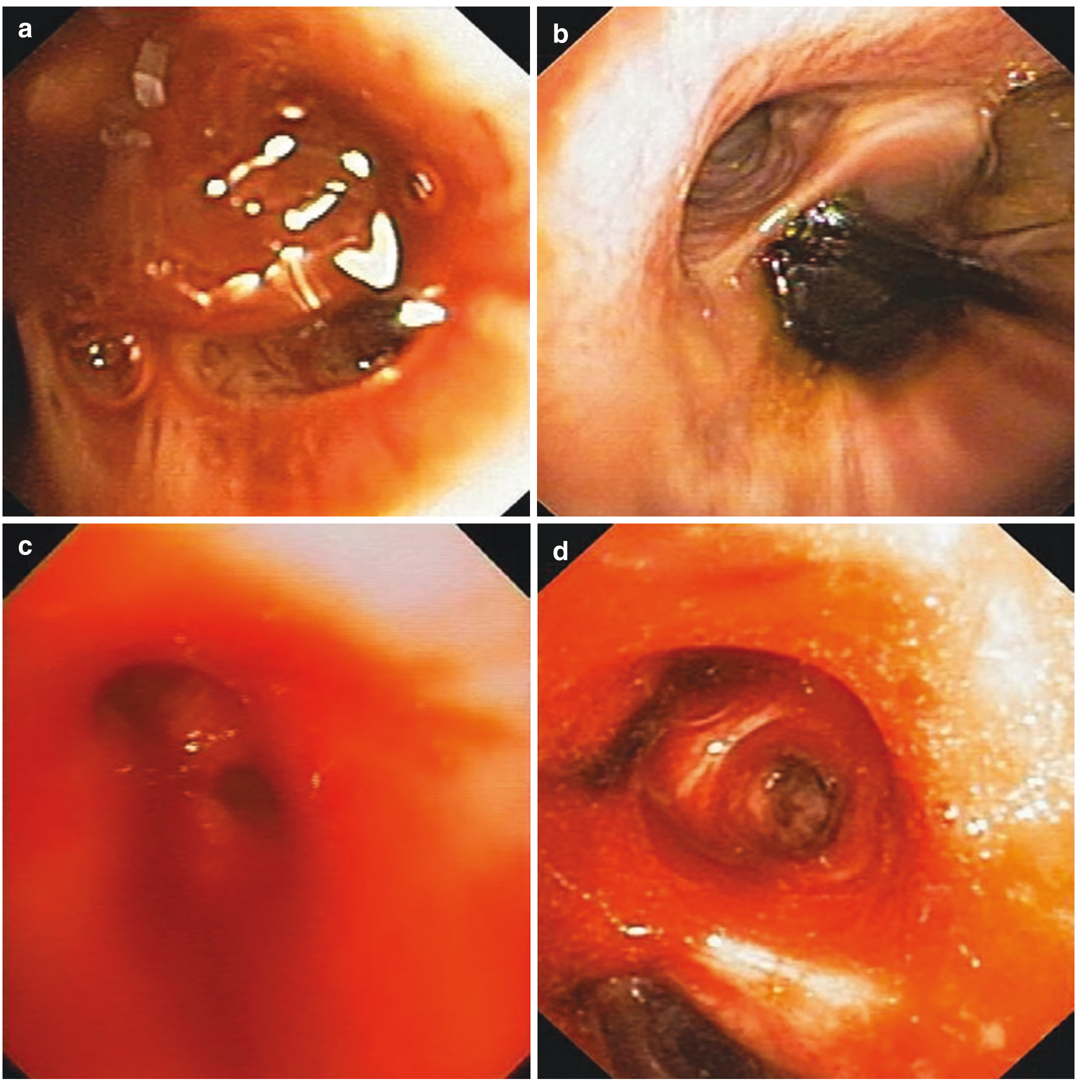

Fig. 41.1 (**a**) Blood clot in the right upper lobe bronchus. (**b**) Blood clot in the right lower lobe bronchus. (**c** and **d**) Active bleeding

remains should be aspirated through repeated small bronchial washes, in order to improve permeability and allow diagnostic examination of the underlying territory. However, in the presence of fresh clots adhering, it is not advisable to aspirate them given the risk of further bleeding. Subsequently, bronchoscopy can be repeated to evaluate whether they can be removed with a smaller risk of rebleeding.

A cryoprobe can be used for the removal of an adherent clot. In order to do that, a cryoprobe is placed in the center of the clot and freezing activated in 3–4 s. The clot will adhere to the end of the probe and be extracted en bloc with the bronchoscope just like a foreign body would do. This procedure should be done through an ET tube or through a rigid bronchoscope in order to have complete control of the airway in the event of bleeding (Figs. 41.2 and 41.3).

3. Causal diagnosis, in case of accessible bronchial lesions.

Bronchoscopy allows us to perform an endobronchial inspection and evaluate muco-

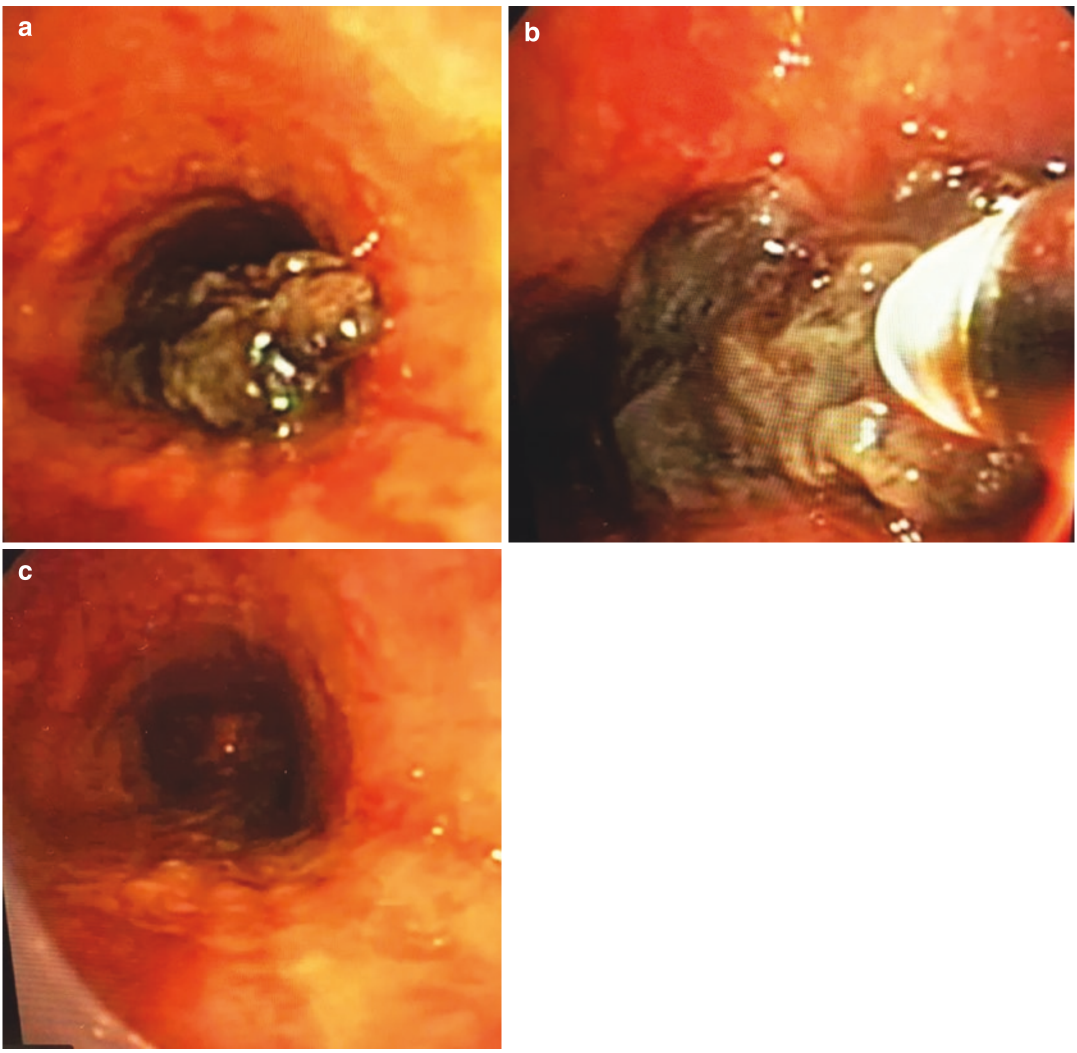

Fig. 41.2 (**a**) Blood clot in trachea. (**b**) Blood clot removal by cryoextraction. (**c**) Trachea after cryoextraction

Fig. 41.3 Right bronchial tree clot

sal changes: hypertrophic or malformed capillary vascular network, areas of inflammatory or infiltrative mucosal thickening, bronchial stenosis, endobronchial tumors, antracosis or antracol stenosis, broncholiths, etc. (Fig. 41.4). In many cases, the changes are non-specific and, therefore, non-diagnostic [22].

In addition to the visual examination, flexible bronchoscopy allows collection of samples for cytohistological and microbiological studies: bronchial lavage, bronchoalveolar lavage in the presence of suspected alveolar hemorrhage, biopsies, and/or bronchial brushing in the presence of lesions suspected of malignancy. In the case of highly vascular lesions, some authors recommend local instillation of 1–2 mL of adrenaline with 1:20,000 dilution, to reduce the risk of further bleeding, although clinical evidence is low [23].

Bronchoscopy also plays a very important role in non-threatening hemoptysis with no apparent radiological alteration.

The existence of a normal chest X-ray in the context of hemoptysis does not exclude the possibility of malignancy or other underlying pathology [5, 24–26]. The probability of malignancy in patients with hemoptysis and normal chest X-ray is low but may reach up to 10% in patients over the age of 40, with a history of smoking [27], and even in patients with mild hemoptysis [28].

Bronchoscopy can detect an endobronchial lesion in 5% of patients with mild hemoptysis and normal chest X-ray [29], and high-resolution computed tomography (HRCT) detects bronchiectasis in up to 70% of cases with severe hemoptysis and normal chest X-rays [7]. Therefore, depending on the type of hemoptysis, bronchoscopy can be performed before or after the complementary radiological tests:

1. Hemoptoic expectoration: If there are no risk factors for cancer, bronchoscopy is indicated when these episodes are recurrent, or when the amount of bleeding increases [29]. In the case of patients with recurrent hemoptysis, the first step is to perform a chest CT scan (HRCT or multidetector computed tomography [MDCT]) as it may be useful to select the most cost-effective endoscopic technique for diagnosis (flexible bronchoscopy or echo bronchoscopy) [7, 11, 30, 31].
2. Evident hemoptysis: If there is no known cause, a bronchoscopy is necessary, especially in patients with risk factors for malignancy. However, depending on the stability of the patient, it may be advisable to perform a chest CT scan first. The combined use of bronchoscopy and MDCT increases the diagnostic yield for locating the bleeding site [7].

If the patient has a normal CT scan, bronchoscopy can diagnose the cause of bleeding in up to 16% of the cases. This percentage increases up to 37% when clinical history is also taken into account [27]. If bronchoscopy does not reveal changes, the patient is considered to have cryptogenic hemoptysis. A combination of CT and negative bronchoscopy has a very low probability of malignancy (1%) after a 6-month follow-up [32].

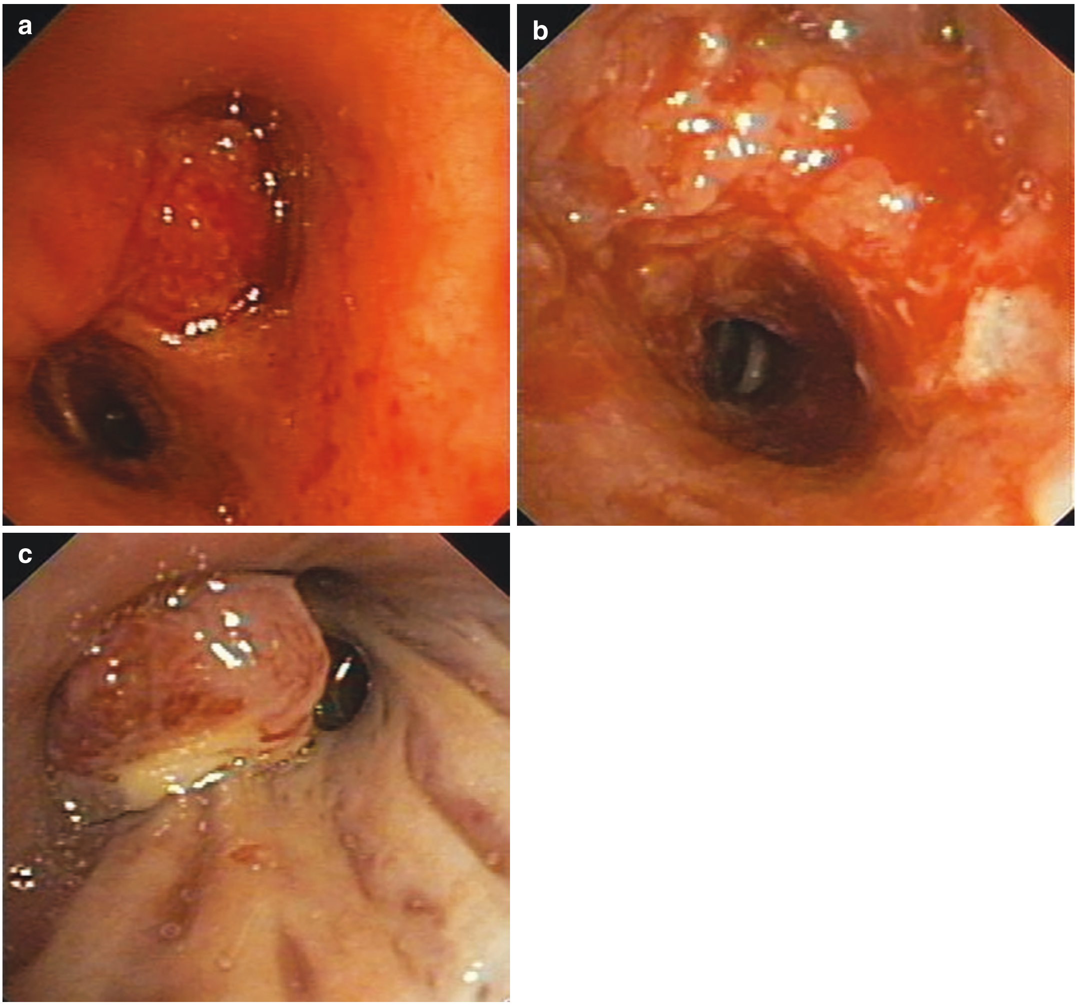

Fig. 41.4 (**a**) Vascular lesion in right upper lobe bronchus. (**b**) Tumoral infiltration at right B6. (**c**) Endobronchial mass in right upper lobe bronchus

Therapeutic Bronchoscopy

Therapeutic bronchoscopy is specifically indicated to eliminate, at least transiently, a risk situation generally in the context of massive or threatening hemoptysis. Therefore, it is an urgent action applied in combination with other life support measures, which seek to recover and keep the patient clinically stable. Diagnosis can then be completed with imaging techniques if the status of the patient allows, and definitive treatment applied. Bronchial, systemic, and/or pulmonary embolization or surgical embolization can be used according to the situation.

Description of the Equipment

See Table 41.2.

Table 41.2 Equipment: Material list frequently used in the management of hemoptysis

1. Bronchial block with flexible bronchoscope and sustained aspiration	
2. Instillation of cold saline	
3. Instillation of hemostatic drugs	
• Vasoconstrictors	• Adrenaline • Antidiuretic hormone derivatives
• Tranexamic acid	
• Fibrinogen-thrombin	
• Biocompatible glue	
4. Other bronchial blockade systems used in case series:	
• Endobronchial stents	• Ultraflex® (Boston Scientific)
• Silicone spigots	• EWS® (Novatech)
• Endobronchial valves	• IBV® (Olympus)
• Oxidized regenerated cellulose	• Surgicel® (Ethicon)
5. Coagulative therapies in endoscopically visible bleeding tumors	
• Argon plasma coagulation	• APC® (Erbe)
• Photocoagulation	
6. Orotracheal tube	
7. Specific orotracheal tubes	
• Selective bronchial intubation	• TCB Univent® (Fuji)
8. Bronchial blockers	
• Embolectomy catheter	• Edwards Fogarty® Catheter
• Bronchial blockers	• Arndt® (Cook) • Cohen® (Cook) • Uniblocker® (Fuji) • EZ-Blocker® (Rüsch)

Adapted from Cordovilla et al. (2016) [7].

Application of the Technique

General Measures

First evaluation of the patient should be oriented to estimate the severity of the condition and decide which treatment is most convenient, and where will it take place.

Generally, hemoptoic sputum does not require hospitalization, but evident and life-threatening hemoptysis does. In the latter case, admission to the ICU is warranted.

Next, a quick and accurate diagnosis should be performed in order to locate the place of bleeding and determine its cause simultaneously.

The objectives of treatment are:

- To secure the airway
- To maintain adequate oxygenation
- To achieve hemodynamic stability
- To locate and stop bleeding
- To identify and treat the cause of hemoptysis

Management of the patient during hospital admission includes a series of general measures:

1. Strict bed rest in lateral decubitus position, the affected side down, in order to protect the airway and prevent aspiration of blood into the unaffected lung.
2. Monitoring of clinical parameters (blood pressure, heart and respiratory rate, oxygen saturation) and quantification of hemoptysis.
3. Supplemental oxygen supply if necessary.
4. Suppression of cough by administering antitussives, avoiding respiratory physiotherapy techniques.
5. Empirical antibiotic treatment, useful in hemoptysis associated with respiratory infections and, in general, to prevent further complications.
6. Nothing by mouth, to avoid aspiration to the airway, and to allow the performance of urgent tests such as bronchoscopy, CT, or arteriography.
7. Establishment of large-bore venous access for fluid administration, availability of a blood reserve, and, if necessary, transfusion of packed red blood cells.
8. Administration of antifibrinolytic agents such as aminocaproic acid and tranexamic acid (TA); they act by inhibiting the clot dissolution process with the consequent reduction in bleeding. There are two clinical trials evaluating the use of TA (Amchafibrin®), both inhaled and intravenously. Although patients with massive hemoptysis were not included, the results indicate that they may reduce the duration of bleeding and the need for interventional procedures [33, 34]. A review of

published patient series concludes that the reduction in bleeding was associated to a low risk of short-term thromboembolic disease [35]. The recommended dose is 500 mg to 1 g intravenously two or three times per day.

Aminocaproic acid (Caproamin®) has been used in case series, as intracavitary instillation in aspergillomas [36, 37].

Protection of the Airway

If there is severe respiratory failure or risk of suffocation (large and rapid bleeding), orotracheal intubation is required, preferably with a thick tube (8–9 mm) to facilitate diagnostic and interventional bronchoscopy [38].

In addition, bronchial blockade may be necessary to control bleeding in order to preserve ventilation of the healthy lung [18, 39]. There are several options to accomplish this:

1. Perform the blockage with the orotracheal tube itself. This is possible in bleeding from the right bronchial tree, since the left main bronchus can be selectively intubated with the aid of the bronchoscope, so that the pneumatic balloon of the tube completely isolates the left lung. It should be taken into account that in tall patients the tube may not be long enough to adequately reach the main bronchus.
2. Use independent bronchial blockers that are placed through a conventional tube:
   (a) Edwards Fogarty® Catheter (n° 7 or higher). This inflatable balloon is introduced parallel to the bronchoscope and it is placed at the selected location under direct vision. This maneuver can be facilitated by rotating the head to the opposite side, in a similar way as the left main bronchus intubation with the rigid bronchoscope, and bringing the end of the tube closer to the tracheal carina. This device cannot be securely anchored during long periods of time, but it may allow blocking completely the bleeding site enough time for a clot to form and adhere. The introduction of the catheter independently of the bronchoscope instead of through its working channel allows continuous suctioning and improved vision.
   (b) Arndt® Endobronchial Blocker (Fig. 41.5). It can be inserted transiently attached to the end of the bronchoscope to be transported to its location [11–13]. It has a transparent head with three ports: one to fix the catheter of the blocking balloon, another for the introduction of the bronchoscope, and the third one for the connection to the ventilator.
   (c) Cohen® Endobronchial Blocker. It is a balloon catheter curved at its distal end to facilitate placement.
   (d) EZ-Blocker®. This catheter has a Y-shaped distal end, to facilitate anchoring in the tracheal carina, and two balloons that can be inflated separately.
3. Perform intubation and blockage with a special orotracheal tube:
   (a) Torque Control Blocker Univent Tube®: This has a bronchial blocker that prolongs the tube itself, designed to occlude any major bronchi with the tube located inside the trachea (Fig. 41.6).
   (b) Bronchoflex ®: This particular tube has a catheter on the outside, through which a Fogarty or similar tool can be inserted, and also provides an external fixation system. Its advantage is that it fully preserves the internal gauge of the tube and facilitates the location of the balloon in any of the main bronchi by rotating the orotracheal tube on its major axis.
   (c) Double-lumen tube: This particular tube allows the blockade of the bleeding site performing selective intubation. Given its reduced caliber, it is not possible to introduce the standard bronchoscope through it, and it is also difficult to anchor since the bleeding site is not directly visible.

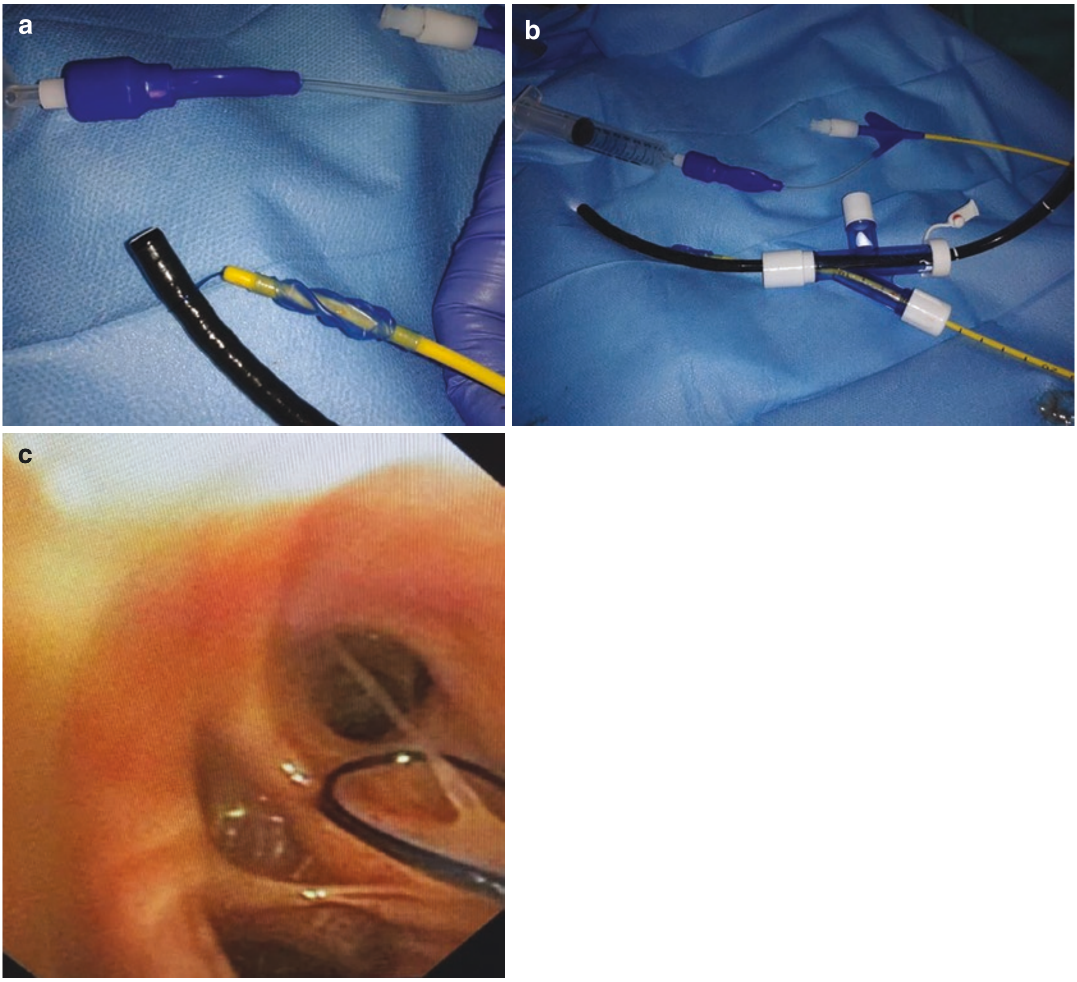

Fig. 41.5 Arndt catheter. (**a**) Catheter fixed at the distal end of the flexible bronchoscope. (**b**) Flexible bronchoscope introduced through the three-headed piece. (**c**) Catheter placed at the selected site

Therapeutic Bronchoscopy

In our experience, flexible bronchoscopy is the first procedure indicated when a patient presents with life-threatening hemoptysis, and hemodynamic instability. It can be performed in the intensive care setting or any other critical area. When a rigid bronchoscope is available, it is advisable to intubate with the rigid tube and through it introduce the flexible endoscope. They can complement each other taking advantage of both instruments:

- Ventilate the patient properly.
- Ensure airway permeability by aspiration of blood and clots with large-caliber probes.
- Perform direct hemostasis on bleeding areas, pressing with the external wall of the distal end of the rigid bronchoscope or by the application of vasoconstrictors or endobronchial coagulant therapies.
- Access the distal bronchial tree.

Therefore, the rigid bronchoscope supplemented with the flexible bronchoscope is the

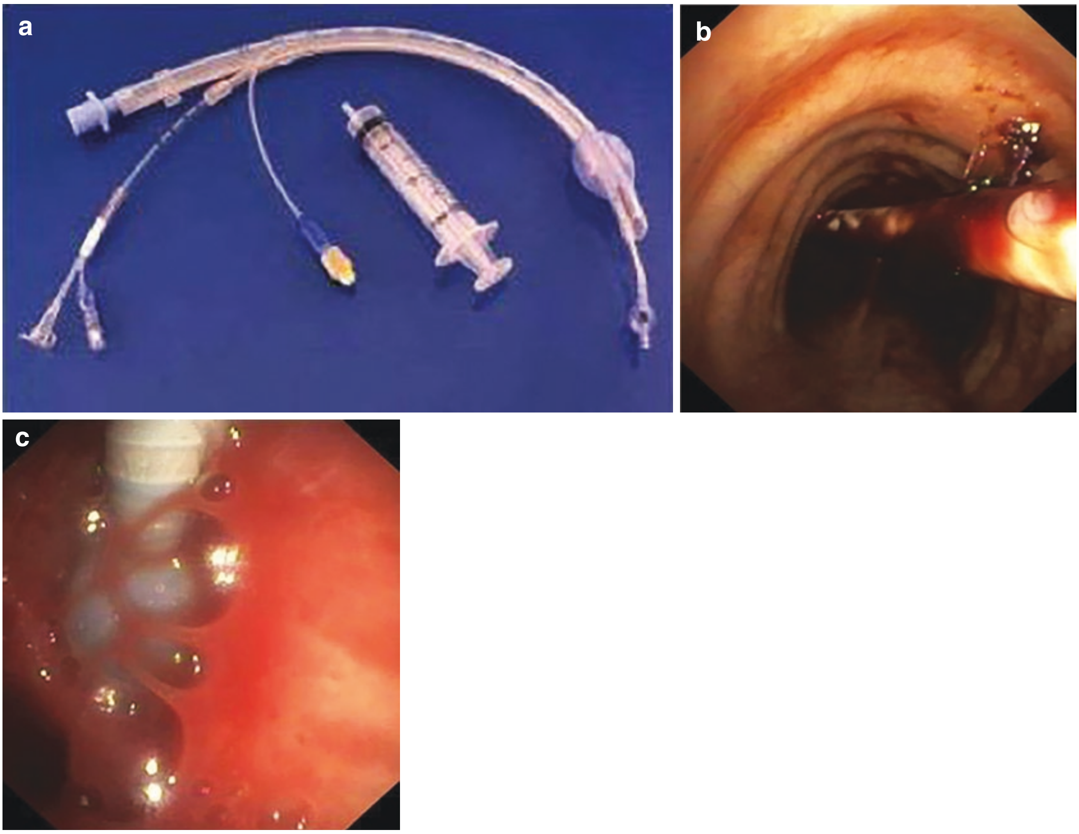

Fig. 41.6 (**a**) Univent tube. (**b**) Univent tube at the trachea, after hemoptysis. (**c**) Inflated balloon at the level of the bleeding bronchus

most complete and safe procedure in life-threatening hemoptysis [39, 40]. However, flexible bronchoscopy remains the most used procedure in these cases, given its broad availability. Rigid bronchoscopy is less available, it requires a special training that not many pulmonary physicians have, and it has to be used in the operating room under general anesthesia or conscious sedation. That implies moving an unstable patient, a risk that may not be affordable in a life-threatening situation.

Once the origin of the bleeding has been identified, if a lung blockade is not necessary, local measures can be applied. Their clinical efficacy is limited, as well as the published evidence.

In addition to the methods described above, other interventional procedures can be performed:

1. Bronchial blockade with the flexible bronchoscope and sustained aspiration in order to cause segmental collapse and stop the bleeding.
2. Selective bronchial blockage through the working channel of the bronchoscope:
   (a) Fogarty n° 5 (5 Fr.) or a similar type of balloon catheter (Olympus B5-2C® and B7-2C® balloon).
   (b) Longer catheters such as the Olympus Multi-3 V Plus B-V232P-A® balloon catheter. This one is a 190-cm catheter that can be inserted through a working channel of 2.8 mm, and insufflated up to 15 mm in diameter. Without deflating the balloon, it can be clamped and cut to stay in place and finally remove the bronchoscope.

3. Selective bronchial blockade using a guide wire: A guide is inserted through the working channel to the chosen bronchus and after removal of the bronchoscope a balloon catheter is placed through the guide. Although this procedure is technically more complicated, it allows the balloon catheter to be located and the bronchoscope removed [41].

   The balloon can be inflated for up to 24–48 h to allow clot formation, although it can be maintained in the airway for up to several days. To prevent mucosal ischemia, it is necessary to deflate it periodically, at least three times a day [42], always under endoscopic vision in order to re-inflate immediately if bleeding persists. If the patient does not bleed again after several hours, the catheter-balloon is withdrawn.
4. Washing of the bronchus with cold saline serum (4°C) using aliquots of 50 mL until bleeding is suppressed, without exceeding 500 mL total volume [43]. The mechanism of action is local vasoconstriction although there are no controlled studies that demonstrate its effectiveness [44].
5. Instillation of hemostatic drugs:
   (a) Vasoconstrictors: Adrenaline diluted to 1:20,000 and applied through the working channel in 1 mL aliquots. Its effect has not been compared in controlled trials and only clinical experience supports its use. In order to minimize its cardiovascular effects in patients at risk, it has been suggested to substitute it for some antidiuretic hormone derivatives such as terlipressin or ornipressin, although reports are anecdotic [45, 46].
   (b) Tranexamic acid can be instilled undiluted on the bleeding site, with an initial dose of 500 mg [47, 48].
   (c) Fibrinogen-thrombin (Tissucol®): It has been used in two case series in hemoptysis cases that could not be controlled with other endoscopic procedures. [49]
   (d) Thrombin slurry: A series of 13 patients showed that hemostasis was achieved in 77% of patients [50].
   (e) Recombinant activated factor VII: Topical hemostatics are not useful in fast and severe hemoptysis, since the blood washes out the hemostatic agent diminishing or abolishing its efficacy. Described in a small series of cases.
6. Other bronchial blockade systems that have been used successfully in series of cases:
   (a) Oxidized regenerated cellulose (Surgicel®): A report by Valipour et al. [49] describes how fragments of this hemostatic and resorbable mesh were introduced into the segmental or subsegmental bronchi causing the hemorrhage to stop. They were previously introduced through the working channel of a standard bronchoscope by pulling them with a flat blade forceps. Once the bleeding site was located, they were pushed into the segmental bronchus with the same forceps. In total, four to ten fragments of 3 × 4 cm were introduced, until hemostasis was achieved. As it was a resorbable material, it was not necessary to extract it later, and the absence of bronchial sequelae was later verified.
   (b) Endobronchial valves: Designed for endoscopic volume reduction, these are used for other purposes such as persistent air leakage or bronchopleural fistula. Isolated cases of their application in the treatment of hemoptysis have also been described [51].
   (c) Silicone plugs (Watanabe spigots) [52, 53]: Initially introduced by Watanabe for endoscopic treatment of bronchopleural fistulas, they have demonstrated their efficacy in the transient tamponade of hemorrhagic segmental bronchi. The insertion and removal are performed by apprehending them with a biopsy forceps, and transporting them at the end of the bronchofiberscope. A series of cases reported by Bylicki accounted for a success rate of 78% [9].
   (d) Stents: In a series of eight patients with cancer-related hemoptysis, bleeding ceased in 75% after stent placement [54].

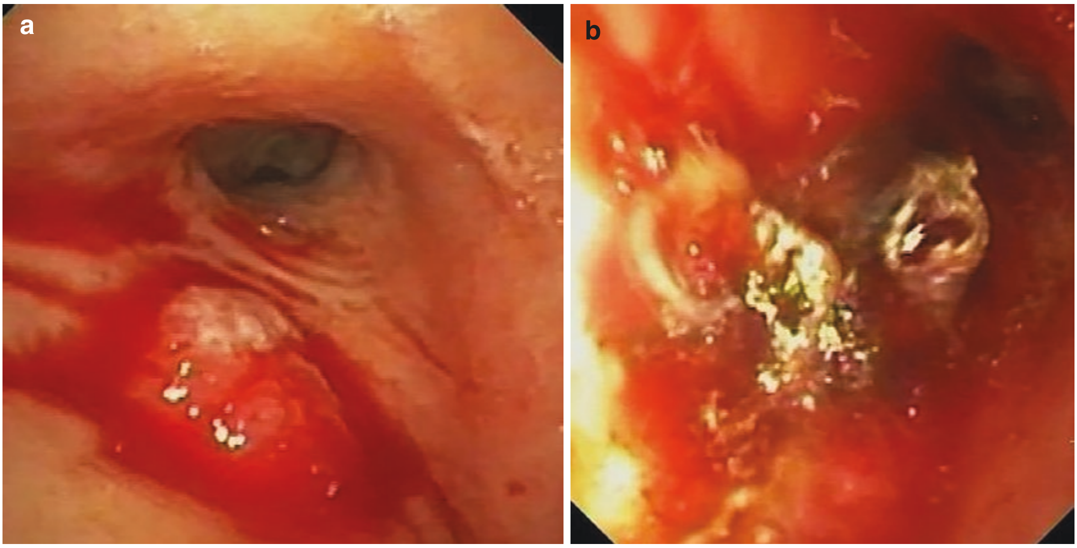

Fig. 41.7 (**a**) Endobronchial lesion in left main bronchus. (**b**) After argon plasma coagulation application

(e) Biocompatible glue: Chawla described its use in 168 patients with an immediate control of bleeding in 90% of patients. After the second application, 7.7% additional patients responded.

7. Laser coagulation: The following are used in cases of accessible, endoscopically visible tumor causing bleeding:
   (a) Laser photocoagulation (Neodymium-Yttrium-Aluminum-Garnet [Nd:YAG], Neodymium-Yttrium-Aluminum-Phosphate [Nd:YAP], diode laser): The efficacy in stopping bleeding ranges from 60 to 74%, although a reduction is achieved in up to 94% of cases [55, 56]. If the bleeding is significant, results are not so favorable [57]. Laser can be effective causing photocoagulation in depth. Very good results have been reported when applied on bleeding endobronchial tumors [55], but little is achieved on severe hemoptysis caused by laser application itself. In this context, the results have not been so favorable [57]. In fact, in highly vascular tumors causing severe hemoptysis, there is a tendency to avoid laser treatments unless an obstruction can be solved with the treatment, and the risks are justified.
   (b) Electrocoagulation with argon plasma: Argon plasma is an electrocoagulation method that does not require tissue contact and acts rapidly superficially. It is less effective than laser in coagulating in depth, and mechanical debridement is more difficult. But it can be very effective, at least transiently, in mucosal lesions whenever cough can be effectively inhibited and there is no significant active bleeding at the time of application. In that case, free blood is coagulated and the treatment does not reach the actual site of bleeding. Increasing the argon flow can facilitate its effect, risking the possibility of gas embolism. In a series of patients with endobronchial lesions responsible for active bleeding, argon plasma coagulation immediately stopped bleeding in 100% of cases [58] (Fig. 41.7).

Evidence-Based Review

See Table 41.3.

Table 41.3 Evidence-based review: List of the most important publications on devices and substances used in endoscopic management of hemoptysis

Thrombin slurry [50]	2018	Peralta et al.	United States	13 patients	Hemostasis was achieved in ten cases (77%) by using standard measures in addition to thrombin slurry
Stents [54]	2017	Barisione et al.	Italy	8 patients	In six cases (75%), the stent placement resulted in bleeding cessation; in one case (12.5%), the bleeding was only briefly reduced
Biocompatible glue [59]	2016	Chawla et al.	India	168 patients	Immediate control of hemoptysis in 151 patients (89.9%); 17 patients had a transient response; a second application of glue was repeated in all of them, out of whom 13 (7.7%) responded to the second procedure; four (2.4%) failed to show any response despite the repeated procedure
Balloon tamponade [60]	2014	Correia et al.	Portugal	3 patients	The balloon was kept inflated for 72 h in the bleeding airway in the first 2 cases with complete resolution of the hemoptysis; in the last case, the balloon was kept inflated for 9 h, until surgery
Silicone Spigot [53]	2012	Bylicki et al.	France	9 patients	Thirteen spigots were inserted; the success rate was 78%
Nd:YAG Laser [55]	2007	Han et al.	Australia	110 patients	76% of patients reported improvement in dyspnea, 94% in hemoptysis, and 75% in cough
Recombinant activated factor VII [61]	2006	Heslet et al.	Denmark	6 patients	A complete and sustained hemostasis after a single dose of rFVIIa was seen in three patients (50%); a sustained hemostasis was achieved by a repeated rFVIIa administration, in the remaining three patients (50%)
Oxidized regenerated cellulose (ORC) [62]	2005	Valipour et al.	Austria	57 patients	Hemostatic tamponed with ORC was successfully performed on 56 of 57 patients (98%) with an immediate arrest of hemoptysis; all patients remained free of hemoptysis for the first 48 h
Argon plasma coagulation (APC) [58]	2001	Morice et al.	United States	60 patients	All patients with hemoptysis experienced a resolution of bleeding immediately after APC

Summary

Hemoptysis is defined as the expectoration of blood from the lower respiratory tract. In most cases, the amount of bleeding is slight, the patient has hemoptoic sputum (sputum staining with blood streaks), and hemoptysis is self-limited. In other cases, the amount is more significant (evident hemoptysis) or may even present as massive hemoptysis (expectoration of fresh blood in significant quantities). However, it is preferable to use the term life-threatening hemoptysis, defined as the one that poses a risk to life for the patient.

The causes of hemoptysis are multiple and varied. The disease causing hemoptysis can affect the airway, lung parenchyma, or pulmonary vessels. Although they vary according to the population studied, the most frequent causes of hemoptysis are bronchiectasis, chronic bronchitis, and bronchogenic carcinoma. On most occasions, bleeding comes from the bronchial arteries; sometimes other systemic non-bronchial arteries may be the source of hemoptysis. In a much lower percentage, the bleeding comes from the pulmonary arteries or from the pulmonary microcirculation.

Bronchoscopy plays a key role in the diagnosis and management of hemoptysis. It allows confirmation in doubtful cases, location of the bleeding point or, at least, location of the affected lung, and the determination of the cause in lesions accessible to it. It can allow the isolation of the hemorrhagic segment or lobe to avoid flooding the non-affecting bronchial tree and reduce the risk of suffocation, by selective intubation or bronchial blockade with balloon, as well as the application of local therapies that contribute to controlling the bleeding.

In the last 3 years, there have been no significant changes in endoscopic management, except the introduction of the use of thrombin gel, although additional studies will be needed.

Recommendations

1. In all patients with hemoptysis, a bronchoscopy is indicated unless the patient no longer has active bleeding and the cause of hemoptysis is known, or when hemoptoic expectoration is self-limited in a patient without risk factors for lung cancer.
2. The first objective of bronchoscopy is to confirm hemoptysis and assess its severity and location.
3. Bronchoscopy should be performed during active bleeding within the first 24–48 h.
4. In life-threatening hemoptysis, bronchoscopy should be performed immediately in order to control bleeding.
5. Location of the source of bleeding requires visualization to determine the bronchus or responsible bronchial area with certainty.
6. In the presence of a fresh clot, its immediate withdrawal should not be performed. It is preferable to have a subsequent examination to reduce the risk of rebleeding.
7. The use of tranexamic acid is recommended to reduce the duration and volume of bleeding in threatening hemoptysis.
8. Intubation in patients with threatening hemoptysis should be performed with endotracheal tubes of 8 mm or larger.
9. Once intubation has been performed, placement of an endobronchial blocker can protect the rest of the airway from the bleeding area.

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