CONTINUING MEDICAL EDUCATION

The Diagnosis and Treatment of Hemoptysis

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SUMMARY

Background: Hemoptysis, i.e., the expectoration of blood from the lower airways, has an annual incidence of approximately 0.1% in ambulatory patients and 0.2% in inpatients. It is a potentially life-threatening medical emergency and carries a high mortality.

Methods: This review article is based on pertinent publications retrieved by a selective search in PubMed.

Results: Hemoptysis can be a sign of many different diseases. Its cause remains unknown in about half of all cases. Its more common recognized causes include infectious and inflammatory airway diseases (25.8%) and cancer (17.4%). Mild hemoptysis is self-limited in 90% of cases; massive hemoptysis carries a worse prognosis. In patients whose life is threatened by massive hemoptysis, adequate oxygenation must be achieved through the administration of oxygen, positioning of the patient with the bleeding side down (if known), and temporary intubation if necessary. A thorough diagnostic evaluation is needed to identify the underlying pathology, site of bleeding, and vascular anatomy, so that the appropriate treatment can be planned. The evaluation should include conventional chest x-rays in two planes, contrast-enhanced multislice computerized tomography, and bronchoscopy. Hemostasis can be achieved at bronchoscopically accessible bleeding sites with interventional-bronchoscopic local treatment. Bronchial artery embolization is the first line of treatment for hemorrhage from the pulmonary periphery; it is performed to treat massive or recurrent hemoptysis or as a presurgical measure and provides successful hemostasis in 75–98% of cases. Surgery is indicated if bronchial artery embolization alone is not successful, or for special indications (traumatic or iatrogenic pulmonary/vascular injury, refractory aspergilloma).

Conclusion: The successful treatment of hemoptysis requires thorough diagnostic evaluation and close interdisciplinary collaboration among pulmonologists, radiologists, and thoracic surgeons.

► Cite this as:

Ittrich H, Bockhorn M, Klose H, Simon M: The diagnosis and treatment of hemoptysis. *Dtsch Arztebl Int* 2017; 114: 371–81. DOI: 10.3238/arztebl.2017.0371

Hemoptysis is defined as the expectoration of blood, alone or mixed with mucus, from the lower respiratory tract (1, 2). It occurs in around 10% of patients with chronic lung disease (2) and is found in ca. 0.1% of all outpatients (3) and almost 0.2% of all inpatients (4) each year. Hemoptysis is a potentially life-threatening emergency and requires rapid diagnosis and treatment. Although over 90% of hemoptyses are self-limiting (5), both the diagnosis and the treatment of massive hemoptysis are challenging (6).

Method

Based on our knowledge and clinical experience we conducted a selective survey of the literature available in the PubMed database. Reviews, randomized controlled trials, registry studies, case-control studies, and case reports were included.

Learning goals

The aim of this article is to familiarize the reader with:

- The clinical, anatomical, and pathophysiological background of hemoptysis,
- the multimodal diagnosis of hemoptysis, and
- the different methods used to treat hemoptysis.

Clinical background

The vast majority of cases of hemoptysis occur in adults (mean age 62 years, male:female ratio 2:1 [4]); only rarely are children affected (7, 8). True hemoptysis, with the source of bleeding in the airways or lungs, must be distinguished from pseudohemoptysis, where the blood originates from the upper gastrointestinal tract or the upper respiratory tract (mouth, nose, or throat). Careful history taking and inspection of the nasopharynx should determine whether the bleeding originates from the respiratory tract (alkaline, bright red, foamy blood, breathing difficulty, sensation of warmth in the thorax) or the gastrointestinal tract (hematinized blood, acid pH, food particles, abdominal pain, nausea).

Severity of hemoptysis

Differentiation of mild and massive hemoptysis is urgent because they are diagnosed and treated differently. Massive bleeding fills the airways and leads to death from asphyxia.

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TABLE 1

Causes and incidence of hemoptysis (from [4])

Cause		Incidence (%)
Cryptogenic		50
Pulmonary disease	Airway infections (bronchitis, pneumonia, lung abscess)	22
	Bronchial carcinoma/metastases	17.4
	Bronchiectases/cystic fibrosis	6.8
	Pulmonary edema/mitral stenosis	4.2
	Tuberculosis ^{*1}	2.7 ^{*1}
	Invasive aspergillosis/aspergilloma	1.1
	Benign bronchial tumors	0.2
	Vasculitis (Behçet syndrome, granulomatosis with polyangiitis (GPA), Goodpasture syndrome)	0.2
Cardiovascular causes	Pulmonary artery embolism	2.6
	Vascular malformations (pulmonary arteriovenous malformation [pAVM]), pulmonary artery aneurysm [Rasmussen aneurysm]), aortobronchial fistula, aorto-/bronchial artery aneurysm, Rendu-Osler disease)	0.2
	Idiopathic pulmonary hemosiderosis	0.1
	Septic embolism/right heart endocarditis	n. d. ^{*2}
	Pulmonary hypertension	n. d. ^{*2}
Other	Iatrogenic: Lung biopsy Right heart catheterization Endoscopic lung volume reduction Anticoagulation treatment or thrombolysis	3.5
	Trauma/lung contusion	0.7
	Foreign body	0.1
	Coagulopathy	n. d. ^{*2}
	Thrombocytopenia	n. d. ^{*2}

^{*1} Most frequent cause of hemoptysis worldwide, especially in the developing countries (12)

^{*2} n. d., no data

The expectoration of blood-tinged sputum and mild or moderate hemoptysis has to be distinguished from massive hemoptysis. The literature definitions of the amount of blood that has to be coughed up for the hemoptysis to count as massive vary between 100 and 1000 mL in 24 h (9–12), but most are in the range of 300 to 600 mL (10). Conservatively treated massive hemoptysis has a mortality rate of 50 to 100% (13, 14). Because of the low volume of the tracheobronchial

space (150 to 200 mL), a collection of blood can swiftly cause a serious problem with gas exchange. The critical rate of bleeding in an individual case depends not only on the amount of blood but also on the patient's mechanism for tracheobronchial blood clearance and the presence of pre-existing impairments of lung function. Death, usually from asphyxia, occurs long before detectable blood loss or the onset of hemorrhagic shock (7). Among the many different causes of hemoptysis,

Symptoms

Hemoptysis can be a symptom of many different diseases. In many cases inflammatory diseases of the airways (bronchitis, pneumonia, tuberculosis, cystic fibrosis) are involved, followed by malignancies.

Mortality

Conservatively treated massive hemoptysis is fatal in 50 to 100% of cases.

TABLE 2

Initial management of hemoptysis

Action	Purpose
Monitor the vital parameters	Registration of pulse-oximetric oxygen saturation (SpO ₂), respiratory and circulatory function (non-invasive blood pressure measurement [NIBP]); assessment of risk involved in interventional procedures and medicinal treatment
Give oxygen	Improvement of oxygenation
Place the patient with the bleeding side down	Prevention of the flow of endobronchial blood into unaffected lung segments
Sedation/anxiolysis	Calming of the patient, facilitation of diagnostic and therapeutic measures (NB: restriction of breathing activity, ability to expectorate, ability to cooperate/communicate)
In massive hemoptysis: endotracheal or, if required, unilateral endobronchial intubation	Maintenance of gas exchange

the most frequent worldwide is tuberculosis (12). In the western world, the cause of half the cases of hemoptysis remains unestablished. In the other half, the causative factors are as follows: (Table 1) (4):

- Inflammatory diseases of the airways (25.8%), including tuberculosis (2.7%) and aspergillosis (1.1%)
- Bronchial carcinoma and metastases (17.4%)
- Bronchiectasis (6.8%)
- Cardiovascular causes such as pulmonary edema/ mitral stenosis (4.2%) and pulmonary artery embolism (2.6%) (4)
- Anticoagulation treatment or thrombolysis (around 3.5%)

Anatomy and pathophysiology

The lungs have a dual blood supply: around 99% of perfusion is via the pulmonary arteries, responsible for gas exchange, and the remaining ca. 1% is from the bronchial arteries (15).

The bronchial arteries run parallel with the bronchi and give off branches that supply the trachea, the bronchi (peribronchial plexus), and the vasa vasorum of the pulmonary vessels (16–18). The origin of the bronchial arteries, often two or three in number, is variable: in around 70% of cases they arise from the thoracic aorta (15, 18), in the remaining 30% from other vascular provinces of the thorax (18). In 5 to 10% of cases the right bronchial artery gives off branches to the anterior spinal artery (ASA) of the spinal cord (11, 19). Bronchopulmonary anastomoses connect the bronchial arteries with the pulmonary arteries. The venous drainage of the blood from

the bronchial arteries ensues primarily via the bronchial veins into the right atrium but also via the pulmonary veins into the left atrium (18).

In the event of impairment of the pulmonary arterial circulation, secretion of neoangiogenetic growth factors leads to bronchial artery proliferation (10, 11, 17, 20).

Such impairments can be caused by the following:

- Hypoxic vasoconstriction
- Pulmonary arterial thromboembolism or thrombosis
- Vasculitis
- Chronic inflammatory or neoplastic lung disease
- Pulmonary arteriovenous malformation (e.g., Osler disease).

Due to the thinner, more fragile walls of the bronchial arteries, the systemic arterial pressure load, and opening of the arteries into chronically inflamed zones or neoplasms, ruptures and hemorrhages of the airway occur and manifest clinically as hemoptysis (17). Angiographic and bronchoscopic studies, together with measurement of the oxygenation of the expectorated blood, have revealed that around 90% of hemoptyses originate in the bronchial arteries, 5% in the pulmonary arteries, and 5% in non-bronchial systemic arteries (7, 12).

Initial assessment

The goal of the initial assessment of a case of hemoptysis is to detect any danger to life by quantifying the bleeding and evaluating the patient's oxygenation. The clinical signs of impaired exchange of gases are

Causes

Among the many different causes of hemoptysis, the most frequent worldwide is tuberculosis. In western countries the cause remains unestablished in around half the cases.

Anatomy

The lungs have a dual blood supply from the pulmonary arteries and the bronchial arteries. The latter arise as a rule from the aorta and are the source of 90% of the cases of hemoptysis.

cyanosis, dyspnea, tachypnea, disturbance of consciousness, and increased work of breathing (21). Out of hospital, a patient suffering massive hemoptysis must receive emergency medical care. The goal of initial management is maintenance of gas exchange (*Table 2*) by administration of oxygen, together with positioning of the patient with the bleeding side down (if known). Should sedation and anxiolysis be necessary, care must be taken that the drug used (e.g., a short-acting benzodiazepine [midazolam]) does not interfere with lung function, clearance of blood from the airways, or the ability of the patient to cooperate and communicate.

In the event of massive hemoptysis and progressive disturbance of gas exchange, one can consider temporary endotracheal intubation with a large-diameter tube, and perhaps unilateral intubation if indicated (6). The vital signs (blood pressure, heart rate, respiratory rate, oxygen saturation), together with blood gas analysis if needed, yield information relevant to gas exchange and the patient's hemodynamics and permit assessment of the risk involved in interventions such as bronchoscopy, angiography, and medicinal treatment (sedation).

Diagnosis

Following the initial assessment to determine any threat to the patient's life, the main goals of the diagnostic work-up in hemoptysis are to identify the site and the cause of the bleeding. To achieve these aims, a standardized procedure should be followed:

- The nature of the event (mild or massive hemoptysis, first event or recurrence) should be established. Any signs of or risk factors for infection should be noted. Furthermore, the physician recording the case history should bear malignancy, cardiac disease, vasculitis, collagenosis, coagulation disorders, and medications (particularly anticoagulants) in mind.
- Laboratory tests should include coagulation parameters, thrombocyte count, and coagulation status. If indicated, parameters of inflammation should be quantified and an immunological work-up performed.
- Either chest radiographs should be obtained at two levels,
- or contrast-enhanced multislice computed tomography with CT angiography of the chest should be carried out.
- If the chest radiography or multislice computed tomography does not pinpoint the cause of

hemoptysis, bronchoscopy should be performed.

Analysis of the findings of this diagnostic work-up yields important information regarding the cause and site of the bleeding (*Table 3*). If the hemoptysis is massive and life-threatening, the diagnostic work-up should not take place out of hospital or in a small hospital. Rather, the patient should be immediately transferred to a center with the necessary bronchoscopic, radiological/endovascular, intensive care, and surgical expertise. The case history and clinical examination provide the first pointers to the severity of the bleeding and begin to explore signs and risk factors of underlying diseases (e.g., teleangiectasias in Osler's disease). The primary clinical chemistry tests in the acute phase (blood count, coagulation status, inflammation parameters) deliver information on the likelihood of an infection and on the patient's cellular and plasmatic coagulation. The secondary lab tests investigate the possibility of immunological or vasculitic causes by determining specific antibodies (c-ANCA, cytoplasmic antineutrophilic cytoplasmic antibody; p-ANCA, perinuclear antineutrophilic cytoplasmic antibody; ANA, antinuclear antibody; ds-DNA-AB, antibody against double-stranded deoxyribonucleic acid).

If the case history and clinical picture are clear and the hemoptysis is mild, chest radiography at two levels is the only diagnostic imaging modality required (*eFigure 1*). It is quick, simple, almost universally available, economical, and has a low radiation burden. The laterality of the bleeding and common causes such as pneumonia, lung abscess, malignant tumor, pulmonary tuberculosis (cavities) or heart defects involving altered cardiac configuration (e.g., mitral stenosis) can often be detected without resorting to other imaging modalities. The sensitivity of conventional radiography is, however, limited: the laterality of the bleeding is established in 33 to 82% of cases, the cause in only 35 to 50% (3, 22, 23).

In the case of massive hemoptysis and whenever the findings of chest radiography are unclear or doubtful, contrast-enhanced multislice computed tomography with CT angiography should be carried out. This procedure takes only a matter of minutes to perform. Multislice computed tomography provides most of the information needed to identify the cause and site of the bleeding in hemoptysis.

The advantages of multislice computed tomography are as follows:

Initial assessment

The initial assessment of a patient with hemoptysis serves to detect any threat to life. The central criterion is oxygenation.

Diagnosis

The diagnostic investigation of hemoptysis includes history taking, clinical chemistry, chest radiography, contrast-enhanced multislice computed tomography with CT angiography, and bronchoscopy.

- Localization of the bleeding (correct identification of the lobe involved in 63 to 100% of cases)
- Correct disclosure of the cause of hemoptysis in 60 to 77% of cases (3, 23–25), e.g.,
 - alveolar hemorrhage
 - bronchiectasis
 - malignant tumor
 - aspergilloma
 - pulmonary arteriovenous malformation, or
 - thoracic aortic or pulmonary artery aneurysm (22, 26).

CT angiography should be carried out using the single breath-hold technique with bolus tracking and injection of contrast medium by means of an injector. ECG triggering can also be used to minimize pulsation artifacts in the thoracic vessels, improving the information with regard to the origin and course of bronchial arteries arising from the aorta as well as ectopic bronchial arteries (27) (*eFigure 2a*). In retrospective ECG, triggering a relatively high radiation dose is required, amounting to a mean 8.2 to 31.8 mSv in adults (28, 29). With prospective ECG triggering the dose can be reduced to a mean 2.1 to 9.2 mSv, because in this mode scanning takes place only at defined intervals of the cardiac cycle; however, adequate preparation of the patient (heart rate <75 bpm) is necessary (28, 29). The information gained from multislice computed tomography reduces the intervention time, radiation dose, and amount of contrast medium needed for subsequent bronchial artery embolization (30). Reconstruction should be carried out in the lung and soft-tissue window (5 mm) together with thin-slice reconstructions (1 mm) to find the openings of the bronchial arteries. Numerous postprocessing techniques, such as multiplanar reconstruction (MPR), maximum-intensity projection (MIP), and three-dimensional (3D) volume and surface imaging (shaded surface display [SSD]), improve visualization of the pulmonary pathology and help to plan the therapeutic intervention (bronchoscopy, bronchial artery embolization, or surgery). The radiation burden for the patient, a disadvantage of all radiographic examinations, has been reduced in recent years by modern low-acquisition protocols (31) and iterative image reconstruction procedures. The many advantages of multislice computed tomography mean that the value of chest radiography in the initial phase is decreasing (effective dose for chest radiography at two levels: 0.1 to 0.2 mSv, for contrast-enhanced multislice computed tomography: 0.5 to 1.5 mSv [32], with ECG triggering:

TABLE 3

Diagnostic methods and the information they yield

Method	Results of analysis	New information
Clinical chemistry	Primary: Inflammation parameters, blood count, coagulation status Secondary: Autoimmune diagnosis	Dependent on cause
Vital parameters (with/without blood gas analysis)	Gas exchange and hemodynamics	Dependent on cause
Chest X-ray (at two levels)	Localization of bleeding Cause of bleeding (pneumonia, lung abscess, bronchial carcinoma, acute or chronic pulmonary tuberculosis)	Determination of side: 33 to 82% Cause: 35 to 50% (3, 22, 23)
Contrast-enhanced multislice computer tomography with CT angiography	Localization of bleeding Cause of bleeding Anatomy and origin of regular or aberrant bronchial arteries	Site: 63 to 100% Cause: 60 to 77% (3, 23–25)
Bronchoscopy	Localization of bleeding (right or left lung, lobe, segment, etc.), cause of bleeding, harvesting of material (microbiology, cytology, histology) Treatment as required: keep airways free of blood, administer vasoconstrictors, tamponade, balloon catheter, laser, argon plasma coagulation	Site: 73 to 93% Cause: 2.5 to 8% (3)

2.1 to 31.8 mSv [28, 29]). One disadvantage of multislice computed tomography is its inability to detect endobronchial neoplasia in the presence of an endobronchial accumulation of blood (33). In this case bronchoscopy is an ideal complementary tool (34).

Digital subtraction angiography is no longer used in primary diagnostic investigation of the bronchial arteries because it is inferior to contrast-enhanced multislice computed tomography in the detection of both bronchial and non-bronchial arteries (35).

Bronchoscopy plays a role in both diagnosis and treatment of hemoptysis (7, 36) and can be performed with a flexible or a rigid device. Bronchoscopy is helpful in localizing the bleeding source (sensitivity 73 to

Diagnostic radiology

Multislice computed tomography is the diagnostic imaging modality that yields most information on the cause and site of hemoptysis.

Massive hemoptysis

Management of massive hemoptysis requires interdisciplinary cooperation by pulmonologists, radiologists, thoracic surgeons and specialists in intensive care. Bronchoscopy plays a role in both diagnosis and treatment.

93%) (3), which may be within the bronchoscopically visualized area or peripheral to it (*eFigure 3*). Bronchoscopy contributes to identifying the cause of hemoptysis in only 2.5 to 8% of cases (3). Bronchoscopically visible sources of bleeding in the central airways are reliably detected and treated locally. For bleeding in the periphery of the lungs, the diagnostic task of bronchoscopy is to roughly localize the source (right or left lung, lobe, segment) as an aid to the planning of subsequent treatment (bronchial artery embolization, surgery) and tissue sampling (for microbiological, cytological, or histological examination) (*eFigure 3*).

No consensus has yet been achieved on the order in which bronchoscopy and multislice computed tomography should be carried out. Some authors prefer to perform multislice computed tomography first, because it is a non-invasive technique and can supply useful information for the planning of bronchoscopy (7, 37). Overall, the combination of bronchoscopy and multislice computed tomography yields the best results in the diagnosis of hemoptysis (22, 25).

Treatment

The primary aim in the treatment of life-threatening massive hemoptysis is to control and stop the bleeding (38). In the absence of both guidelines and meta-analyses on the treatment of hemoptysis, the following course of action is recommended, based on the current state of knowledge as established by a survey of the literature in PubMed (3, 38, 39):

Conservative treatment

Mild or moderate hemoptysis can often be managed by conservative treatment of the underlying pathology (e.g., treatment of the infection or anti-inflammatory measures). Furthermore, optimization of the coagulation status, particularly during anticoagulation treatment, can be achieved by stabilizing coagulation and thus stopping the bleeding (40). Small studies of hemoptysis of varying etiology (e1, e2) or in cystic fibrosis (e3) have shown that hemoptysis can be controlled by antifibrinolytic treatment with tranexamic acid.

Bronchoscopy

Because the life of a patient with pulmonary bleeding is threatened above all by filling of the airways with blood, not by blood loss in itself, the primary therapeutic goal of bronchoscopy is to ensure

sufficient exchange of gases by freeing the airways of blood and then keeping them free. This is best achieved by rigid bronchoscopy, which not only ventilates the patient but also permits the use of large, wide-bore instruments for swifter removal of blood from the airways (e4). Liquid blood can simply be aspirated. In contrast, the removal of clots by suction or with instruments for retrieval of foreign bodies is often difficult. One effective way of dealing with blood clots is to use a cryoprobe, with which even a large clot can be frozen in a matter of seconds and then extracted (e5).

Further therapeutic applications of bronchoscopy depend on the site of the bleeding source, which may be located beyond the reach of bronchoscopy in the periphery of the lungs or within the bronchoscopically visualizable part of the tracheobronchial system.

Therapeutic rinsing with vasoconstrictive substances such as cold physiological saline solution (e6) or diluted catecholamine solutions is possible, provided the potential systemic complications are borne in mind.

In the event of persisting peripheral pulmonary bleeding, the goal of bronchoscopy is specific isolation of the affected area by occlusion of the relevant bronchus, to prevent overflow of blood into other airways and other parts of the lungs. The more precisely the site of bleeding can be localized, the more specifically the afferent airway can be occluded. In the case of severe bleeding, it may be difficult to pinpoint the source. It is necessary to at least determine whether the right or the left lung is involved. Occlusion can be by tamponade or balloon catheter. Tamponade is achieved by using forceps to insert sterile surgical swabs with radiographic contrast strips into the bronchial system on the side affected until cessation of bleeding is achieved. Specific occlusion even beyond the segmental bronchi is possible with balloons. Special models have been developed that can be inserted via a flexible bronchoscope, permit withdrawal of the bronchoscope by means of a removable screw valve, and offer an additional lumen ending beyond the balloon for administration of therapeutic fluids (e7, e8). It is advisable to administer antibiotic treatment and remove the tamponade or balloon catheter within 72 h to avoid postocclusion infection.

If there is persistent bleeding from the central airways, the therapeutic goal of bronchoscopy is

Conservative treatment

Mild or moderate hemoptysis can often be managed by conservative treatment of the underlying pathology (e.g., treatment of the infection or anti-inflammatory measures).

Bronchoscopy

The primary therapeutic goal is to ensure sufficient exchange of gases by freeing the airways of blood and then keeping them free.

FIGURE

Flow chart—The diagnosis and treatment of hemoptysis (+ = “clearly diagnostic,” i.e., the source of bleeding is precisely identified)
CTA, Computed tomography angiography; MSCT, multislice computed tomography

treatment of the visible bleeding source. Local interventional bronchoscopy options include, among others, treatment of the site of bleeding by laser or by argon plasma coagulation. If a laser is used, visible vascular structures can be accurately targeted (e9, e10). Argon plasma coagulation possesses particularly favorable physical properties and also enables treatment of bleeding sources in positions that are not orthograde to the catheter (e11, e12).

Minimally invasive endovascular treatment

Bronchial artery embolization (BAE), a minimally invasive endovascular technique, has become the method of choice for treating massive and recurrent hemoptysis (9, e13–e15). Bronchial artery embolization should be carried out as soon as possible after contrast-enhanced multislice computed tomography and bronchoscopy. In mild and moderate hemoptysis of malignant origin (bronchial carcinoma, metastases) the barrier to bronchial artery embolization should be set lower, because the mortality rate in such cases is much higher (21%) than in patients with hemoptysis of benign (5%) (22, e16). The goal of bronchial artery embolization is reduction of the systemic arterial perfusion pressure in the bronchial arteries of the affected area in order to stop the bleeding (11). When planning bronchial artery embolization, it must be borne in mind that patients with chronic pulmonary disease are particularly likely not to tolerate lying supine and the intervention may have to be interrupted owing to the

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Bleeding from the periphery of the lung

The goal of bronchoscopy is isolation of the affected area by occlusion of the relevant bronchus, to prevent overflow of blood into other airways and other parts of the lungs.

Bleeding from the central airways

The goal of bronchoscopy is control of bleeding by local treatment of the visible source.

coughing up of blood. Thus it must be ensured that the patient receives an adequate supply of oxygen before and during bronchial artery embolization. In massive hemoptysis, interventional bronchoscopic occlusion of the relevant bronchus and/or intubation of the patient will be necessary prior to bronchial artery embolization. There is no agreement on the necessity of neurological examination before bronchial artery embolization or on the monitoring of motor and sensory functions in the lower extremities during bronchial artery embolization. The monitoring of somatosensory evoked potentials (SSEP) has the advantage of early detection of spinal complications (e.g., ischemia).

Bronchial artery embolization must be carried out by an experienced interventional radiologist using a high-resolution digital subtraction angiography unit. The examination begins with selective angiography of the bronchial artery origins. The diameter of the bronchial arteries increases to several millimeters in patients with chronic inflammatory lung disease, especially cystic fibrosis (18) (*eFigure 2b*). Active bleeding is demonstrated in only 3.6 to 10.8% of cases (e17, e18). The following findings are pointers to bronchial artery pathology as the source of bleeding (e14, e17, e19):

- Bronchial artery diameter >2 mm
- Tortuosity of the bronchial arteries
- Shunts
- Aneurysms
- Extravasation of contrast medium
- Hypervascularized zones of lung parenchyma

Identification of a pathologically altered bronchial artery is followed by embolization with a suitable material (microparticles, embolization spirals, liquid embolizing agents). Before proceeding to embolization, however, the diagnostic findings should be considered in their totality, the existence of branches supplying the spine must be excluded (NB: supply of anterior spinal artery), and the risk of systemic embolism owing to shunts between the bronchial arteries and the pulmonary arteries or pulmonary veins has to be weighed up.

If the hemoptysis continues after bronchial artery embolization, aberrant bronchial arteries (e.g., arising from the internal mammary artery) should be sought and transpleural collaterals excluded as bleeding source. If still no bleeding site is found, the pulmonary arterial circulation has to be investigated (10) to exclude pulmonary artery aneurysms (e.g., Rasmussen aneurysm in cavernous tuberculosis) and pulmonary

artery malformations as source of the hemoptysis (ca. 5 to 10.5% of cases) (e20, e21). Should any such structure be found, embolization spirals or balloons are used to eliminate the bleeding (e22, e23).

Two frequently occurring side effects of bronchial artery embolization are transient chest pain (24 to 91%) and dysphagia (0.7 to 18.2%) (e18). One of the most serious complications is transverse myelitis owing to spinal cord ischemia following accidental embolization of spinal arteries (1.4 to 6.5%) (e18, e24).

The technical success rate of bronchial artery embolization, i.e., the proportion of cases in which the bleeding is stopped, is 75 to 98% (e16, e25, e26). The recurrence rate is 1 to 27% within 1 month of bronchial artery embolization (e18, e25, e27) and 10 to 55% between 1 and 46 months (e15, e24). In the long term, the rate of elimination of bleeding is much higher for benign than for malignant underlying diseases. The rebleeding-free survival rate is 94% after 1 year, 87% after 5 years, and 87% after 10 years in benign disease, compared with 34% after 1 year in cases of malignant etiology (e25). The high long-term recurrence rate is explained by the fact that bronchial artery embolization treats only the symptoms; in the absence of causal treatment, or if the underlying pulmonary disease progresses, renewed hemoptysis is inevitable (e28).

Aspergilloma shows particularly high rates of recurrent bleeding (30 to 100%) (e14, e29, e30) and of death within 1 month of bronchial artery bleeding (50%) (e31). Patients with this disease often require not only several bronchial artery embolization procedures but also aggressive infectiological/surgical management (e32, e33).

Surgical treatment

Up to the 1980s the treatment of choice for hemoptysis was surgery, associated with a mortality of 37 to 42% in the emergency scenario and 7 to 18% in the interval between bleeding events (9). The mortality has remained high, at 4 to 19%, in more recent studies (e34–e37). This is due to compromised hemodynamic and respiratory function caused by continuing intraoperative bleeding and bronchial tree filling, resection of lung parenchyma (lobectomy/pneumonectomy) owing to imprecise localization of the bleeding source, the resulting loss of lung capacity, lack of knowledge of the lung function parameters, and uncertainty regarding the tolerable extent of resection (e38).

For these reasons, transarterial bronchial artery embolization has become established as the safest and

Bronchial artery embolization

The goal is reduction of the systemic arterial perfusion pressure in the bronchial arteries of the affected area in order to stop the bleeding.

Success rate

The technical success rate of bronchial artery embolization is 75 to 98%.

most effective non-surgical treatment option in massive or recurrent hemoptysis (e13, e14, e24, e32). Surgery remains firmly indicated in bleeding from necrotizing tumors, in cavernous tuberculosis, and in refractory aspergilloma, in cases where bronchial artery embolization has been unsuccessful, and in special circumstances such as traumatic or iatrogenic pulmonary vascular injury (7, e35, e38, e39). Whenever possible, surgery should be an elective procedure after multidisciplinary hemostatic treatment, identification of the cause of bleeding, and definition of the necessary extent of resection (e38, e40). Surgical resection reaches its limits in the presence of extensive carcinoma with invasion of the trachea, mediastinum, heart, or great vessels and in patients with severe comorbidity, advanced pulmonary fibrosis, or pulmonary emphysema (e41).

Removal of the source of bleeding means that surgical resection is a definitively curative procedure with excellent long-term results: the recurrence rate is only 2.2 to 3.4% (e38, e39). The *Figure* shows a possible algorithm for the diagnosis and treatment of hemoptysis (based on [39]).

Conflict of interest statement

The authors declare that no conflict of interest exists.

Manuscript submitted on 9 May 2016, revised version accepted on 16 January 2017

Translated from the original German by David Roseveare

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Surgical treatment

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Supplementary material

For eReferences please refer to:
www.aerzteblatt-international.de/ref2117

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Please answer the following questions to participate in our certified Continuing Medical Education program. Only one answer is possible per question. Please select the most appropriate answer.

Question 1

What is the commonest cause of hemoptysis?

- a) Endometriosis
- b) Rasmussen aneurysm
- c) Infectious airway disease
- d) Pulmonary arteriovenous malformation
- e) A foreign body in the airways

Question 2

What is usually the reason for the high mortality in massive hemoptysis?

- a) Anemia
- b) Shock due to blood loss
- c) Secondary pneumonia
- d) Asphyxia
- e) Tachycardia

Question 3

Which vessels are the commonest source of bleeding in hemoptysis?

- a) Pulmonary arteries
- b) Bronchial arteries
- c) Alveolar capillaries
- d) Bronchial veins
- e) Pulmonary veins

Question 4

From what proximal diameter are bronchial arteries considered pathologically widened?

- a) >1 mm
- b) >1.5 mm
- c) >2 mm
- d) >3 mm
- e) >4 mm

Question 5

Which diagnostic method yields the most information on the cause and site of hemoptysis?

- a) Thoracoscopy
- b) Perfusion scintigraphy
- c) Chest radiography at two levels
- d) Non-contrast multislice computed tomography
- e) Contrast-enhanced multislice computed tomography

Question 6

Which diagnostic examination can best be dispensed with in hemoptysis?

- a) Bronchoscopy
- b) Thoracoscopy
- c) Contrast-enhanced multislice computed tomography
- d) Blood count and lab tests for coagulation
- e) Chest radiography

Question 7

A patient presents with mild hemoptysis. Radiography shows parenchymal densities. Which treatment option should be pursued?

- a) Immediate bronchial artery embolization
- b) Therapeutic bronchoscopy
- c) Conservative treatment of the underlying cause
- d) Pulmonary artery embolization
- e) Targeted occlusion with a balloon catheter

Question 8

Which bronchoscopic interventional procedure is particularly suitable for local treatment of a bleeding source in the central airways?

- a) Insertion of a a balloon catheter
- b) Insertion of a tamponade
- c) Cryotherapy
- d) Unilateral bronchial intubation
- e) Argon plasma coagulation

Question 9

What is the most severe complication of bronchial artery embolization?

- a) Transverse myelitis
- b) Short-segment aortic dissection
- c) Bronchial artery dissection
- d) Cerebral ischemia
- e) Bronchial wall necrosis

Question 10

Which disease often requires a surgical procedure/resection despite bronchial artery embolization?

- a) Rasmussen aneurysm
- b) Aspergilloma
- c) Pulmonary arteriovenous malformation
- d) Sarcoidosis
- e) Acute bronchitis

Supplementary material to:

The Diagnosis and Treatment of Hemoptysis

by Harald Ittrich, Maximilian Bockhorn, Hans Klose, and Marcel Simon

Dtsch Arztebl Int 2017; 114: 371–81. DOI: 10.3238/arztebl.2017.0371

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eCase 1

A 43-year-old man has mild hemoptysis as a result of previous recurrent episodes of pneumonia. Clinical examination shows a slight reduction in general status. Auscultation of the lungs reveals wet rales over the base of the right lung. A QuantiFERON test is negative. Chest radiography shows infiltrative densities in the right lower field in the presence of, for example, pneumonia or alveolar hemorrhage (*eFigure 1*). Multislice computed tomography with CT angiography demonstrates spotty/confluent densities and bronchiectases in the middle lobe. Bronchoscopy shows small amounts of blood in the right main bronchus. Bronchial lavage with microscopy and polymerase chain reaction for *Mycobacterium tuberculosis* is negative, but *Pseudomonas aeruginosa* is found. The patient is treated with antibiotics according to the antibiogram. The symptoms have fully resolved by the time of discharge. Hemoptysis does not recur.

eFigure 1: Chest radiography in mild hemoptysis with middle lobe densities from alveolar hemorrhages

eCase 2

A 36-year-old woman has recurrent hemoptysis (one or two times per month with loss of small to considerable amounts of blood). She is known to have cystic fibrosis. In the past 15 to 20 years she has had multiple episodes of hemoptysis, frequently leading to hospital admission for intravenous administration of antibiotics. Clinical examination shows a current reduction in general status. Her nutritional status is normal. Auscultation of the lungs reveals bilateral wet rales. Multislice computed tomography with CT angiography (*eFigure 2a*) demonstrates ubiquitous bronchiectases and cystic fibrosis with multiple widened bronchial arteries and a peribronchial infiltrate in the left lower lobe. Bronchoscopy shows pronounced active bleeding from the periphery of the left lower lobe (*eFigure 3*). Owing to the considerable bleeding and the pathologically altered bronchial arteries, the treatment is uncomplicated bronchial artery embolization with microparticles and embolization spirals. Hemoptysis is no longer occurring at the time of discharge. Treatment with antibiotics according to the antibiogram ensues (*eFigure 2b*).

eFigure 2: Pathologically widened bronchial arteries (arrows) in cystic fibrosis: (a) contrast-enhanced multislice computed tomography with CT angiography; (b) digital subtraction angiography

eFigure 3: Bronchoscopic visualization of blood in the left main bronchus originating from the periphery of the left lower lobe