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A 44-year-old man with hemoptysis: A review of pertinent imaging studies and radiographic interventions

ABSTRACT

Chest radiography, conventional computed tomography (CT), multidetector CT angiography, and conventional thoracic angiography are all useful in assessing patients with hemoptysis. In this paper we outline our approach to assessing and treating these patients.

KEY POINTS

We recommend chest radiography in the initial stages of evaluation of hemoptysis, whether the hemoptysis is massive or nonmassive.

In cases of hemoptysis that is intermittent (whether massive or nonmassive) in patients whose condition is stable, CT, multidetector CT angiography, and bronchoscopy are all useful.

In cases of hemoptysis that is active, persistent, and massive, multidetector CT angiography, bronchoscopy, and conventional bronchial angiography are all useful, depending on the hemodynamic stability of the patient.

Bronchial artery embolization is the preferred noninvasive first-line treatment for hemoptysis and offers an excellent alternative to surgery for patients who are poor candidates for surgery.

A 44-YEAR-OLD MAN comes to the emergency room because of light-headedness and fatigue. He says he has had several similar but milder episodes in the last several months. He also mentions that he thinks he has been coughing up blood. He says he has no major medical or surgical problems of which he is aware, but he appears confused and unable to give an accurate history. No family members can be contacted for further history at the moment.

Physical examination reveals nothing remarkable, but the patient does cough up some blood during the examination. His hemoglobin level is 6.0 g/dL (reference range 13.5–17.5).

What imaging tests would be helpful in this patient's evaluation?

HEMOPTYSIS HAS MANY CAUSES

Hemoptysis is defined as the expectoration of blood originating from the tracheobronchial tree or the pulmonary parenchyma.

Most cases of hemoptysis are benign and self-limited; life-threatening hemoptysis is rare.[1–3] However, hemoptysis can be a sign of serious tracheopulmonary disease.

The bleeding can be from the large (TABLE 1) or the small (TABLE 2) pulmonary vessels. Bleeding from the small vessels is known as diffuse alveolar hemorrhage, and it characteristically presents as alveolar infiltrates on chest radiography. In these cases, further imaging studies provide little benefit.[4] This paper will focus on the imaging of and radiographic interventions for large-vessel bleeding.

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TABLE 1

Causes of hemoptysis from large-vessel bleeding

Infectious causes
Acute or chronic bronchitis
Bronchiectasis
Cystic fibrosis
Lung abscess
Lung parasites (ascariasis, schistosomiasis, paragonimiasis)
Mycetoma, cavitary fungal infection
Pneumonia
Necrotizing pneumonia
Nontuberculous mycobacteria
Tuberculosis

Cardiovascular causes
Aortic aneurysm or bronchovascular fistula
Heart failure
Mitral stenosis
Pulmonary embolism or infarction
Right-sided endocarditis
Septic pulmonary embolism

Neoplastic causes
Bronchial adenoma
Lung cancer
Metastatic disease

Vasculitic causes
Behçet disease
Systemic lupus erythematosus
Takayasu arteritis
Wegener granulomatosis

Other causes
Arteriovenous malformations
Aspirated foreign body
Bioterrorism (pneumonic plague, tularemia, T2 mycotoxin)—rare
Bleeding diathesis secondary to antiplatelet agents in cardiac patients
Bronchial artery aneurysm
Chronic pulmonary interstitial fibrosis
Drugs (cocaine, anticoagulants, penicillamine)
Factitious hemoptysis
Idiopathic pulmonary hemosiderosis
Pneumoconiosis
Pulmonary artery aneurysm (Rasmussen, mycotic, arteritis)
Pulmonary contusion, trauma
Pulmonary endometriosis
Pseudosequestration
Unknown (cryptogenic)

TABLE 2

Causes of hemoptysis from small-vessel bleeding

Immunologic and vasculitic causes
Acute lung allograft rejection
Antiglomerular basement membrane disease
Behçet disease
Henoch-Schönlein purpura
Isolated pulmonary capillaritis
Microscopic polyangiitis
Mixed cryoglobulinemia
Primary antiphospholipid antibody syndrome
Wegener granulomatosis

Cardiovascular and coagulatory causes
Anticoagulants
Antiplatelet agents
Idiopathic thrombocytopenic purpura
Mitral stenosis
Thrombotic thrombocytic purpura

Other causes
Diffuse alveolar damage
Idiopathic pulmonary hemosiderosis
Lymphangiomyomatosis
Pulmonary capillary hemangiomatosis
Pulmonary veno-occlusive disease
Tuberous sclerosis

Without prompt treatment, up to 80% of patients with massive hemoptysis die

The causes of hemoptysis are numerous; common causes of bleeding from the large vessels nowadays include bronchiectasis, fungal infections, tuberculosis, and cancer.[1,5,6] Still, no cause is identified in 15% to 30% of all cases,[1,2,5] even after extensive evaluation.

Definition of 'massive' hemoptysis can vary

Various definitions of the severity of hemoptysis have been proposed. The threshold of "massive" hemoptysis has been defined as as low as 100 mL/24 hours and as high as 1 L/24 hours; the most common definition is 300 mL, or about 1 cup.[2,3,5–10]

However, the patient's cardiorespiratory status must also be considered.[5,6,9] If the patient cannot maintain his or her airway, a small amount of bleeding could be life-threatening and should be considered significant or massive. Thus, we define massive hemoptysis as more than 300 mL of blood within 24 hours *or* any amount of blood with concurrent cardiorespiratory compromise.

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It is important to recognize massive hemoptysis quickly, because without urgent treatment, up to 80% of patients may die.[5,6,11] This can sometimes pose a challenge, as the history may not always be helpful and the patient's perception of massive hemoptysis may differ from the clinically accepted definition. For example, in a patient without respiratory compromise, we would not consider blood-tinged sputum or small amounts of blood that add up to 1 to 2 teaspoons (5–10 mL) to be massive, although the patient might. On the other hand, hemoptysis with cardiorespiratory compromise must be considered significant (and very possibly massive) until proven otherwise, even if the amount of blood is small.

Massive hemoptysis is usually the result of erosion of systemic (rather than pulmonary) arteries by bronchial neoplasm, active tuberculosis, or aspergilloma.[6,9,12,13] Arteriovenous malformations and pulmonary artery aneurysms are much less common causes.[5,11,13]

IMAGING AND DIAGNOSTIC OPTIONS

Most cases of hemoptysis have an identifiable source and cause of the bleeding at the time of initial diagnosis.[14] Currently, there is no consensus on what is the best workup for hemoptysis. Still, a complete evaluation includes patient history, physical examination, bronchoscopy, laboratory tests, and imaging studies (**FIGURE 1**). Imaging studies that can be helpful include chest radiography, conventional computed tomography (CT), multidetector CT angiography, and conventional angiography.

Chest radiography

Chest radiography is an excellent initial imaging test for evaluating hemoptysis. It is quick and inexpensive and can provide insight into acute chest problems. As mentioned above, in cases of alveolar hemorrhage, radiography typically reveals alveolar infiltrates.[4] In cases of hemoptysis due to large-vessel bleeding, radiography can reveal a variety of pertinent findings, such as a mass, pneumonia, chronic lung disease, atelectasis, or a cavitary lesion (**FIGURE 2**). Even if the findings are nonspecific (such as in pneumonia), radiography can narrow the location of the problem to a single lobe or at least to a single lung, and this information can guide further evaluation by bronchoscopy[4,9]

In as many as 40% of cases of hemoptysis, however, the findings on chest radiography are normal or do not reveal the source of the bleeding.[15,16] Approximately 5% to 6% of patients with hemoptysis and normal results on radiography are eventually found to have lung cancer.[14] Thus, while a localizing finding on radiography is helpful, a normal or nonlocalizing finding warrants further evaluation by other means, including conventional CT, multidetector CT angiography, or bronchoscopy.

Computed tomography

Both conventional CT and multidetector CT angiography are quick and noninvasive ways to locate the site of bleeding, determine the cause of bleeding (**FIGURE 3, FIGURE 4**), and create a map to guide further therapy.[5,6,11,13]

CT is superior to fiberoptic bronchoscopy in finding a cause of hemoptysis, its main advantage being its ability to show distal airways beyond the reach of the bronchoscope, and the lung parenchyma surrounding these distal airways.[5,15,16] In locating the site of bleeding, CT performs about as well as fiberoptic bronchoscopy.[5]

5%–6% of patients with hemoptysis and normal radiographs have lung cancer

However, while CT imaging is extremely useful in evaluating bleeding from larger vessels, it adds little information beyond that obtained by chest radiography in cases of diffuse alveolar hemorrhage.[4]

Multidetector CT angiography is the optimal CT study for evaluating hemoptysis. In addition to showing the lung parenchyma and airways, it allows one to evaluate the integrity of pulmonary, bronchial, and nonbronchial systemic arteries within the chest. It is at least as good as (and, with multiplanar reformatted images, possibly even better than) conventional angiography in evaluating bronchial and nonbronchial systemic arteries. Multidetector CT angiography is recommended before bronchial artery embolization to help one plan the procedure and shorten the procedure time, if the patient is stable enough that this imaging study can be done first.[6,12,13]

The iodinated contrast material used in CT angiography can cause contrast nephropathy in patients with renal failure. At Cleveland Clinic, we avoid using contrast if the

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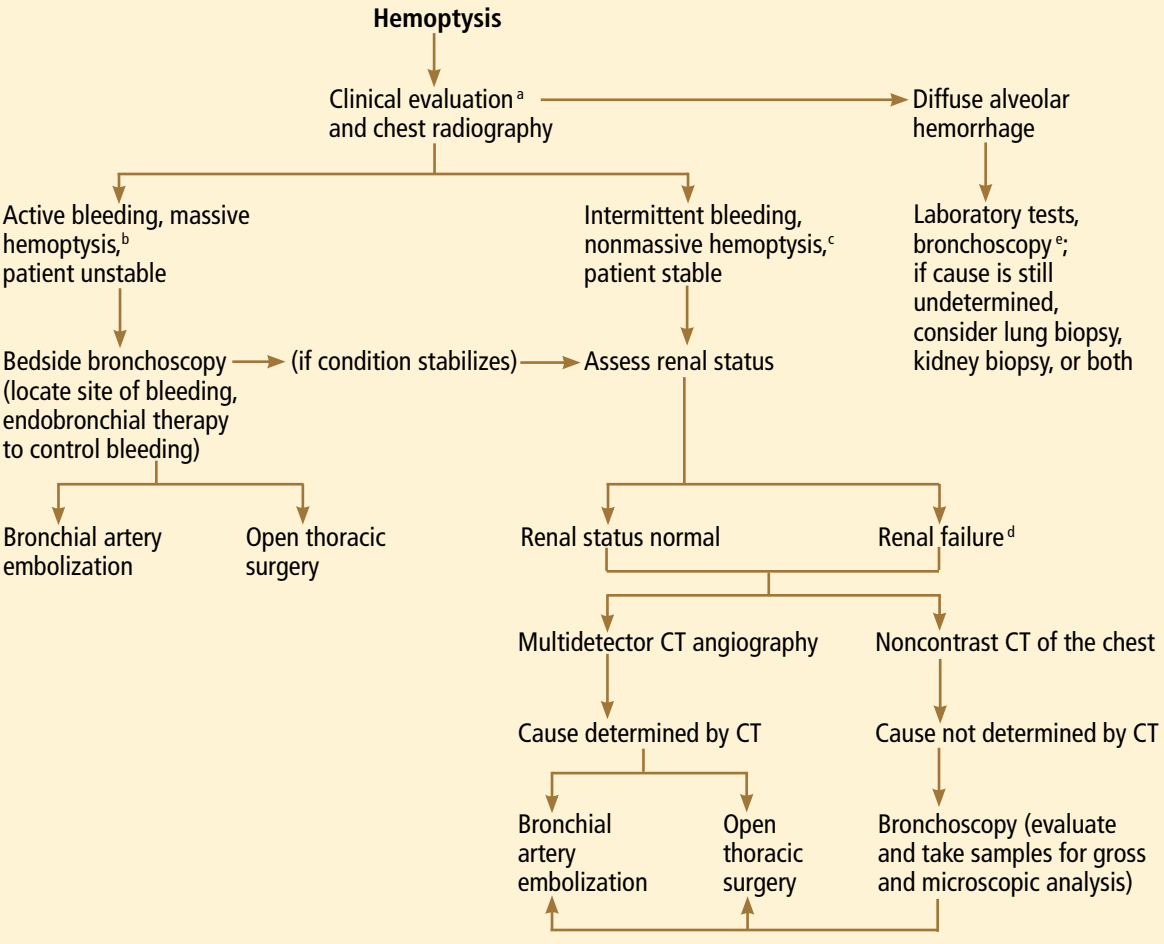
Our algorithm for hemoptysis management



[a] A complete history focusing on characterizing the hemoptysis, changes in color of urine and stool, bleeding patterns, history of smoking, and a complete review of systems is recommended. A complete physical examination is recommended with focus on the cardiac and respiratory systems. Sputum should be sent for Gram stain, culture, cytologic study, acid-fast stain, and bacterial, fungal, and mycobacterial cultures as needed. Pertinent laboratory studies include complete blood cell count, prothrombin time, partial thromboplastin time, urinalysis, serum chemistries, and in hemodynamically unstable patients, an arterial blood gas measurement.[2]

[b] Massive hemoptysis: > 300 cc blood expectorated within 24 hours or any amount of hemoptysis resulting in cardiorespiratory decompensation.

[c] Nonmassive hemoptysis: < 300 cc blood expectorated within 24 hours.

[d] Serum creatinine level ≥ 2.0 mg/dL or a normal or slightly abnormal creatinine that is rapidly rising.

[e] Blood or blood protein in the urine requires a fresh urine sediment examination. Additional laboratory tests recommended in the evaluation of alveolar hemorrhage include antineutrophil cytoplasmic antibody, antiglomerular basement membrane antibodies, serum markers for collagen vascular disease, and erythrocyte sedimentation rate. Early bronchoscopy is important, and bronchoalveolar lavage specimens should be sent for routine cultures and fungal and viral cultures as indicated. If no cause is determined, biopsy of lung, kidney, or both may be necessary. Kidney biopsy is recommended for suspected antiglomerular basement membrane disease or collagen vascular disease.[4]

FIGURE 1

patient's serum creatinine level is 2.0 mg/dL or greater or if it is rapidly rising, even if it is in the normal range or only slightly elevated; a rapid rise would indicate acute renal failure (eg, in glomerulonephritis). In these cases, we recommend CT without contrast.

CT of the chest has revealed malignancies in cases of hemoptysis in which radiography and bronchoscopy did not.[15,17] Although CT is more than 90% sensitive in detecting endobronchial lesions, it has limitations: a blood clot within the bronchus can look like a tumor, and acute bleeding can obscure an endobronchial lesion.[5] Thus, bronchoscopy remains an

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FIGURE 2. Chest radiograph in a 52-year-old man with cough and hemoptysis. The ill-defined mass in the right lower lobe was found to be squamous cell carcinoma.

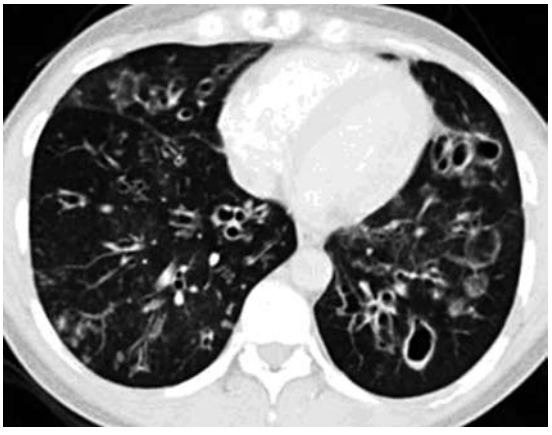

FIGURE 3. A computed tomographic scan shows cystic dilatation of the bronchi bilaterally, consistent with cystic bronchiectasis.

important, complementary diagnostic tool in the evaluation of acute hemoptysis.

Bronchoscopy

Bronchoscopy is overall much less sensitive than CT in detecting the cause of the bleeding,[15,16,18] but, if performed early it as useful as CT in finding the site of bleeding,[5,9] information that can be helpful in planning further therapy.[19] It may be more useful than CT in evaluating endobronchial lesions during acute hemoptysis, as active bleeding can obscure an endobronchial lesion on CT.[5] However, the distal airways are often filled with blood, making them difficult to evaluate via bronchoscopy.

In approximately 10% of cases of massive hemoptysis, rigid bronchoscopy is preferred over fiberoptic bronchoscopy, and it is often used in a perioperative setting. However, its use is not usually possible in unstable patients receiving intensive care. Instead, flexible fiberoptic bronchoscopy can be used in patients whose condition is too unstable to allow them to leave the intensive care unit to undergo CT. Flexible fiberoptic bronchoscopy does not require an operating room or anesthesia,[19] and can be done in the intensive care unit itself.

Not only can bronchoscopy accurately locate the site of bleeding, it can also aid in controlling the airway in patients with catastrophic hemorrhage and temporarily control bleeding through Fogarty balloon tamponade, direct application of a mixture of epinephrine and cold saline, or topical hemostatic tamponade therapy with a solution of thrombin or fibrinogen and thrombin.[2,3,19] It also provides complementary information about endobronchial lesions and is valuable in providing samples for tissue diagnosis and microbial cultures.

Diagnostic angiography has limitations

Although it is possible to bypass radiography, CT, and bronchoscopy in a case of massive hemoptysis and to rush the patient to the angiography suite for combined diagnostic angiography and therapeutic bronchial artery embolization, this approach has limitations. Diagnostic angiography does not identify the source of bleeding as well as CT does.[6] It is important to locate the bleeding site first via CT, multidetector CT angiography, or bronchoscopy. Diagnostic angiography can be time-consuming. The procedure time can be significantly shorter if CT, bronchoscopy, or both are done first to ascertain the site of bleeding before bronchial artery embolization.[1,6] Another reason that performing CT first is important is that it can rule out situations in which surgery would be preferred over bronchial artery embolization.[6]

Avoid CT angiography in patients with renal failure, as it may cause contrast nephropathy

In more than 90% of cases of hemoptysis requiring embolization or surgery, the bleed-

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FIGURE 4. A computed tomographic scan in a 44-year-old man with hemoptysis. The solid mass on the left is a mycetoma within a thin-walled cavity in the left upper lobe.

ing is from the bronchial arteries.[5,6,9,11–13] However, bronchoscopy before bronchial artery embolization is unnecessary in patients with hemoptysis of known cause if the site of bleeding can be determined from radiography or CT and if no bronchoscopic airway management is needed.[18]

BRONCHIAL ARTERY EMBOLIZATION: AN ALTERNATIVE TO SURGERY

The death rate in surgery for massive hemoptysis is 40%; in embolization, 7.1%–18.2%

After a cause of the hemoptysis has been established by radiography, CT, or bronchoscopy, bronchial artery embolization is an effective first-line therapy to control massive, life-threatening bleeding.[6] It is an alternative in patients who cannot undergo surgery because of bilateral or extensive disease that renders them unable to tolerate life after a lobectomy.[6,12,18]

Indications for bronchial artery embolization include failure of conservative management, massive hemoptysis, recurrent hemop-tysis, and poor surgical risk. It is also done to control bleeding temporarily before surgery.[1]

Another indication for this therapy is peripheral pulmonary artery pseudoaneurysm, which is found in up to 11% of patients undergoing bronchial angiography for hemoptysis. These patients typically present with recurrent hemoptysis (sometimes massive) and occasionally with both hemoptysis and clubbing. Most of these patients have either chronic active pulmonary tuberculosis or a mycetoma complicating sarcoidosis or tuberculosis. Occlusion of the pulmonary artery pseudoaneurysm may require embolization of bronchial arteries, nonbronchial systemic arteries, or pulmonary artery branches.[20]

Surgery, however, is still the definitive treatment of choice for thoracic vascular injury, bronchial adenoma, aspergilloma resistant to other therapies, and hydatid cyst.[6] A cardiothoracic surgeon should be consulted in these cases.

Outcomes of embolization

Aside from the cases in which surgery is indicated, bronchial artery embolization (**FIGURE 5**) is a very successful minimally invasive therapy that controls bleeding immediately in 66% to 90% of patients.[1,7,21] It is the preferred emergency treatment for massive hemoptysis, as the death rate is 7.1% to 18.2%, which, though high, is considerably less than the 40% seen in emergency surgery for massive hemoptysis.[6]

If a patient with massive hemoptysis undergoes successful bronchial artery embolization but the bleeding recurs 1 to 6 months later, the cause is likely an undetected nonbronchial systemic arterial supply and incomplete embolization.[1,22] Late rebleeding (6–12 months after the procedure) occurs in 20% to 40% of patients and is likely to be from disease progression.[1,7]

Common complications of bronchial artery embolization are transient chest pain and dysphagia. Very rare complications include subintimal dissection and spinal cord ischemia due to inadvertent occlusion of the spinal arteries.[6] Another complication in patients with renal failure is contrast nephropathy, the risk of which must be weighed against the possible consequences—including death—of not performing bronchial artery embolization in a patient who cannot undergo surgery.

CASE REVISITED: CLINICAL COURSE

In the patient described at the beginning of this article, a chest radiograph obtained in the emergency room showed an area of nonspecific consolidation in the left upper lung. Conventional chest CT was then ordered (**FIGURE 4**), and it revealed a cavitary lesion in the left upper lobe, consistent with aspergilloma.

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Bronchoscopy was then performed, and it too indicated that the bleeding was coming from the left upper lobe. Samples obtained during the procedure were sent to the laboratory for bacterial and fungal cultures.

In the meantime, family members were contacted, and they revealed that the patient had a history of sarcoidosis.

The patient went on to develop massive hemoptysis. Although the treatment of choice for mycetoma is primary resection, our patient's respiratory status was poor as a result of extensive pulmonary sarcoidosis, and he was not considered a candidate for emergency surgery at that time. He was rushed to the angiography suite and successfully underwent emergency bronchial artery embolization.

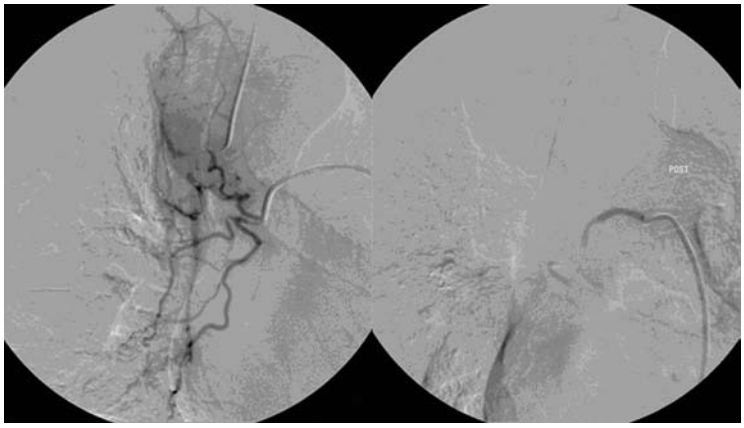

FIGURE 5. A pathologic bronchial artery to a mediastinal tumor before (**left**) and after (**right**) embolization with polyvinyl alcohol particles.

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