American College of Radiology
ACR Appropriateness Criteria®
Hemoptysis

Variant 1: **Massive (life-threatening) hemoptysis. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Arteriography bronchial with embolization	Usually Appropriate	☢☢☢☢
CTA chest with IV contrast	Usually Appropriate	☢☢☢
Radiography chest	Usually Appropriate	☢
CT chest with IV contrast	Usually Appropriate	☢☢☢
CT chest without IV contrast	May Be Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢

Variant 2: **Nonmassive (non–life-threatening) hemoptysis. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
CT chest with IV contrast	Usually Appropriate	☢☢☢
CTA chest with IV contrast	Usually Appropriate	☢☢☢
Radiography chest	Usually Appropriate	☢
Arteriography bronchial with embolization	May Be Appropriate	☢☢☢☢
CT chest without IV contrast	May Be Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢

Variant 3: **Recurrent hemoptysis. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
Radiography chest	Usually Appropriate	☢
Arteriography bronchial with embolization	Usually Appropriate	☢☢☢☢
CTA chest with IV contrast	Usually Appropriate	☢☢☢
CT chest with IV contrast	May Be Appropriate	☢☢☢
CT chest without IV contrast	Usually Not Appropriate	☢☢☢
CT chest without and with IV contrast	Usually Not Appropriate	☢☢☢

HEMOPTYSIS

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Summary of Literature Review

Introduction/Background

Hemoptysis is defined as the expectoration of blood from the lung alveoli or airways of the lower respiratory tract. The most common causes of hemoptysis vary based on the level of the medical care facility and the geographic location of the patient. For example, in the outpatient primary care setting, the most common causes of hemoptysis are acute respiratory tract infections, chronic obstructive pulmonary disease, malignancy, and bronchiectasis [1]. In large tertiary referral centers in North America and Europe, the most common causes of hemoptysis are bronchiectasis, respiratory infections, and lung carcinomas [2-4]. Tuberculosis and its sequelae remains the most prevalent cause of hemoptysis in developing countries [5]. Additional causes include, but are not limited to, sarcoidosis, autoimmune disease resulting in capillaritis or cavitation, coagulopathies, sequelae from respiratory infections, and vascular causes such as pulmonary arteriovenous malformations, pulmonary pseudoaneurysms, and pulmonary artery aneurysms [6]. Pulmonary embolus is an uncommon cause of hemoptysis, and there is only a single study that reports pulmonary embolus as one of the primary causes of hemoptysis [7]. Hemoptysis without a known cause despite extensive investigation by both CT and bronchoscopy is termed "cryptogenic hemoptysis" and accounts for approximately 20% of patients initially presenting with hemoptysis [3,8]. Although cryptogenic hemoptysis has been reported as high as 50% [2], this upper range is likely inflated because of incomplete investigation with either CT or bronchoscopy.

Hemoptysis severity is inconsistently defined throughout the literature. A growing consensus supports the categories of massive and nonmassive hemoptysis rather than "mild, moderate, or severe" hemoptysis. Massive hemoptysis, defined as hemoptysis that can threaten life, has been suggested to be as low as >100 mL of expectorated blood in 24 hours [9]. Confounding factors in determining this lower threshold includes the difficulty in clinically quantifying hemoptysis and the discordance between the quantity of expectorated blood and retained blood within the lungs. Although fatal massive hemoptysis is more commonly a result of asphyxiation rather than exsanguination, the amount of blood loss resulting in death will vary based on coexisting cardiopulmonary comorbidities. Concomitant hypotension has been suggested as an independent factor in determining massive hemoptysis. Of note, morbidity and mortality have been more closely associated with the rate of hemoptysis rather than the quantity of hemoptysis [10]. Therefore, for the purposes of this review, massive hemoptysis is defined as "hemoptysis placing the patient at high risk for asphyxiation or exsanguination."

Initial Imaging Definition

Imaging is considered at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- there are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care) OR
- there are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously in which each procedure provides unique clinical information to effectively manage the patient's care).

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Special Imaging Considerations

For the purposes of distinguishing between CT and CT angiography (CTA), ACR Appropriateness Criteria topics use the definition in the ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography (CTA) [11]:

> *"CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial or venous enhancement. The resultant volumetric dataset is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3-D renderings."*

All elements are essential: 1) timing, 2) reconstructions/reformats, and 3) 3-D renderings. Standard CTs with contrast also include timing issues and recons/reformats. Only in CTA, however, is 3-D rendering a required element. This corresponds to the definitions that CMS has applied to the Current Procedural Terminology codes.

Discussion of Procedures by Variant

Variant 1: Massive (life-threatening) hemoptysis. Initial imaging.

Massive hemoptysis is clinically subdivided into "clinically unstable" and "clinically stable." In unstable massive hemoptysis, the primary focus is patient stabilization and resuscitation. Bronchoscopy has become a mainstay of clearing the airways of blood clots and potentially tamponading the site of bleeding to maintain ventilation [6]. Radiographs are recommended to assess the amount of lung affected by aspirated blood and endotracheal tube placement. Data from a large tertiary hemoptysis-referral center in France were used to devise a reproducible scoring system for the assessment of in-hospital mortality from hemoptysis. This scoring system includes a chest radiograph that horizontally divides each lung into an upper and lower half, roughly resulting in four quadrants. Two or more opacified lung quadrants on a frontal chest radiograph were shown to correspond with increased risk of mortality [12].

A treatment pathway of interventional bronchoscopy, surgery, or arteriography with artery embolization in clinically unstable patients with massive hemoptysis is based on multiple factors, including central or distal location of the site of bleeding, cardiopulmonary comorbidities, and access to interventional radiology. When radiographs demonstrate diffuse alveolar hemorrhage, the clinical focus is reversal of the inciting cause, which is commonly systemic with this presentation. Because the focus for clinically unstable patients with massive hemoptysis is therapeutic rather than diagnostic, this is not a separate variable. Once the patient has been stabilized, the patient can be categorized into this first variable, "massive (life-threatening) hemoptysis, clinically stable."

Arteriography Bronchial with Embolization

Conventional arteriography is no longer considered a diagnostic modality and is performed with the intent to treat hemoptysis with bronchial or systemic nonbronchial artery embolization. Within this article, the abbreviation "BAE" refers to either bronchial or systemic nonbronchial artery embolization. The majority of recent publications on massive hemoptysis focus on BAE outcomes and embolic agents. BAE has become the first-line therapy in treating massive hemoptysis, including those who will eventually be definitively treated with surgery. Immediate success of BAE ranges from 70% to 99% [5,13]. Recent studies on BAE with large patient populations are primarily from Asia, where tuberculosis is typically the most common cause of hemoptysis. These studies demonstrate very high BAE success rates:

- Pei et al: 112 patients from China with massive hemoptysis, all due to active or sequelae of tuberculosis, were treated with BAE, resulting in 87% of patients with immediate hemoptysis cessation or minimal residual hemoptysis at 14 days and 76% of patients who remained free of hemoptysis at 1 year [14].
- Bhalla et al: 334 patients from India underwent BAE, with approximately 80% presenting with massive hemoptysis (subclassified in this study as moderate or severe), and a minority of patients who were children. In this study, 74% of patients treated because of tuberculosis, and 14% required repeat BAE for recurrent hemoptysis [15].
- Shao et al: 344 patients from China with varying degrees of hemoptysis, 55% with tuberculosis sequelae and 29% with bronchiectasis, underwent BAE with a 94% immediate success rate; 82% remained free from hemoptysis at 1 month [16].
- Agmy et al: 348 patients from Egypt with either massive or moderate recurrent hemoptysis underwent BAE with a 95% immediate success rate and a 90% success rate at one month following the procedure. The top etiologies of hemoptysis were active or sequelae from tuberculosis (57%) and bronchiectasis (22%) [17].

- Woo et al: 406 patients from Korea, including 70% with massive hemoptysis, were stratified based on the embolic agent used for BAE. This study reported a success rate of 77% (polyvinyl alcohol particles, n = 293) and 88% (n-butyl-2-cynoacrylate agent, n = 113) at 1 year. In this study, 37% of cases were due to active or sequelae from tuberculosis, and 29% of cases were due to bronchiectasis [18].
- Shin et al: 169 patients from Korea with active or sequelae from tuberculosis were treated with BAE, 59% of whom presented with massive hemoptysis. Of the 169 patients, 94% demonstrated complete hemoptysis cessation or minimal residual hemoptysis at 1 month following BAE, and 76% of patients remained free of hemoptysis at 1 year [19].

Massive hemoptysis in the developed world shows a higher prevalence of malignancy over tuberculosis etiologies. In a study of 26 patients with either lung cancer or lung metastasis causing hemoptysis, treatment with BAE resulted in a 75% immediate success rate. The 6-month mortality rate remained high at 55% [20]. Razazi et al [21] prospectively studied patients with massive hemoptysis related to non–small-cell lung cancer. Of the 125 patients in the study, 102 patients underwent BAE, and 82 patients achieved bleeding cessation (80% BAE success rate).

Massive hemoptysis due to an unknown cause (ie, cryptogenic hemoptysis) has similar BAE outcomes compared with hemoptysis from a known cause. An early study treating cryptogenic hemoptysis with BAE was published in 2010 [22]. In this study, 39 patients with cryptogenic hemoptysis who presented with varying severity of hemorrhage were all treated medically. Hemoptysis remained uncontrolled in 21 patients, who subsequently underwent successful BAE; 2 patients had recurrent hemoptysis. A second retrospective review compared BAE outcomes of 26 patients with cryptogenic hemoptysis to 152 patients with a known cause of hemoptysis over the same interval. Both groups showed a 100% immediate success rate following BAE, and both groups demonstrated similar recurrence rates (12% versus 25%, respectively, which was not statistically different) [8].

Over 90% of massive hemoptysis is due to a systemic arterial supply, and therefore conventional pulmonary arteriography is rarely performed. An early study documenting this was authored by Sbano et al [23], reporting a pulmonary arterial bleeding origin in 8 of 76 patients with massive hemoptysis. Although all of these patients were initially treated with BAE, 7 out of 8 patients required additional pulmonary artery embolization. Shin et al [24] identified 10 patients with pulmonary artery pseudoaneurysms (PAPs) out of 286 patients presenting with massive hemoptysis undergoing BAE. These authors reported a pulmonary artery embolization success rate above 90%. Khalil et al [25] retrospectively reviewed 272 patients, 13 of whom had bleeding from a pulmonary artery origin. Of these 13 patients, 11 underwent pulmonary artery embolization, all of which were successful. The largest study to date isolating patients with massive hemoptysis due to a pulmonary arterial source identified 24 patients from a cohort of 712 patients presenting with massive hemoptysis [26]. This study reported an 88% pulmonary artery embolization success rate.

Overall, BAE is now universally accepted as a safe and effective intervention for the treatment of massive hemoptysis.

CT Chest with IV Contrast

The utility of CT in determining the cause for hemoptysis was first established in the late 1990s. Naidich et al [27] reported CT-bronchoscopic correlations of 58 patients with hemoptysis (severity not specified), showing CT was superior to bronchoscopy in both the diagnosis of lung cancer (17 CT positive versus 15 bronchoscopy positive) and definitive staging of lung cancer (48% versus 14%, respectively). They also established that CT was superior to radiography. Of the 23 normal chest radiographs, subsequent CT provided a definitive cause in 9 patients. Revel et al [28] published data from 80 patients with massive hemoptysis demonstrating CT was more efficient than the previous reference standard of bronchoscopy in identifying the etiology of hemoptysis (77% versus 8%, respectively; $P < .001$).

Larger, more recent studies supporting the use of CT with intravenous (IV) contrast as a diagnostic tool in massive hemoptysis include:

- Fartoukh et al: In a subset of 162 patients with varying severity of hemoptysis, the cause of bleeding was deduced from medical history, known comorbid conditions, physical examination, chest radiograph, and bronchoscopy in 69% of patients. Subsequent CT identified a cause of bleeding in an additional 20% of patients ($P < .001$) [3].

- Agmy et al: Of 348 patients studied, CT examinations (use of contrast not reported) were performed in 300 patients, and the CT findings were suggestive of the etiology in 288 patients (83%) [17].
- Dabo et al: Out of 86 patients obtaining a CT or CTA for either massive or chronic recurrent hemoptysis, imaging was suggestive of a cause in 94% of cases [29].

CT with IV contrast has also been used with the intention of preprocedural planning for BAE. An early study by Yoon et al [30] reported a close concordance between CT with IV contrast and conventional arteriography, showing 82% of the 57 arteries determined to cause hemoptysis during arteriography for BAE were prospectively detected on CT with contrast. The largest recent study groups focusing on the benefit of CT with contrast in preprocedural planning for BAE include:

- Woo et al: Out of 485 patients undergoing BAE, 403 had a diagnostic CT, resulting in accurate localization of the site of bleeding in 367 patients (91%) based on arterial abnormalities and extent of pulmonary disease [18].
- Seon et al: A total of 161 patients with massive hemoptysis underwent a contrast-enhanced CT (91) or CTA (71), with 1 patient getting both studies. The aim of this study was to determine the site of bleeding for subsequent BAE by morphologic rather than vascular abnormalities on CT and comparing these findings with bronchoscopy. Although tuberculosis, inflammatory lesions, bronchiectasis, and pneumonia showed concordance rates with bronchoscopy below 50%, specific lesions such as a mycetoma or malignancy had an over 90% concordance rate [31].

Based on these studies, CT can facilitate BAE planning by potentially identifying a specific lesion or isolating the bleeding artery based on increased arterial diameter and wall irregularity in a high percentage of cases.

CT Chest without IV Contrast

Several early studies have established the use of CT in the diagnosis of hemoptysis used high-resolution CT (HRCT). For example, Tsoumakidou et al [32] followed 184 patients with varying degrees of hemoptysis, demonstrating that HRCT identified a cause in 41% of patients with a normal chest radiograph. In 2008, Khalil et al [25] reported on the utility of performing HRCT in the emergent management of hemoptysis in the intensive care unit.

With the advancement of technology, the vast majority of CT examinations can be reformatted to the resolution of the previously ordered HRCT, and there is rarely an added benefit of HRCT to a routine CT. Khalil et al [33] subsequently published a study retrospectively evaluating patient outcomes comparing a cohort of patients who had a CT without IV contrast with a cohort of patients who underwent CTA. There was a statistically significant difference in the number of emergent surgical resections following embolization in patients who did not have a CTA preceding the BAE (10% CT without cohort versus 4.5% CTA cohort). IV contrast is also well established as an agent that significantly improves the visualization of mediastinal structures. As discussed above, IV contrast shows an added benefit to preprocedural embolization planning.

Therefore, CT chest without IV contrast is only warranted in the diagnosis of massive hemoptysis in patients with poor renal function or life-threatening contrast allergy.

CT Chest without and with IV Contrast

Although early studies used CT chest protocols without IV contrast followed by with IV contrast, there are no data to support any added value of a CT chest without IV contrast prior to administering contrast in the diagnosis of hemoptysis or in preprocedural planning for BAE.

CTA Chest

CTA has also proven to be beneficial in detecting bronchial and nonbronchial arteries in preprocedural planning. Remy-Jardin et al [34] documented the utility of CTA for BAE preprocedural planning, demonstrating an 86% concordance rate between the 58 abnormal arteries identified on CTA compared with the gold standard of conventional arteriography. Hartmann et al [35] retrospectively reviewed 251 patients (with varying severity of hemoptysis) who were imaged by CTA. Of these 251 patients, 214 had CTAs that were of diagnostic quality without confounding central mediastinal pathology. The purpose of this study was to analyze the frequency of aberrant and ectopic locations of bleeding arteries. Of the 24 patients who required BAE, 36% had aberrant bronchial origins, and the authors asserted that CTA information guided successful and rapid catheterization in 22 patients and precluded repeated arteriograms. CTA information changed treatment strategy in 2 of the 24 patients with aberrant arteries, resulting in initial treatment with surgical ligation rather than BAE because of an anticipated high risk of

embolization based on vascular location. Mori et al [36] were also early in advocating CTA for preprocedural planning, identifying bronchial artery diameter as an important diagnostic clue on CTA in determining the bleeding artery requiring embolization. Jiang et al [37] reported results from 818 patients obtaining a CTA for preprocedural BAE planning, which isolated 6 aberrant arteries that would not have been detected by standard angiographic procedures. Lin et al [38] also reported a high concordance rate between CTA and conventional arteriography, reporting that 107 of the 110 arteries embolized (97%) were prospectively identified on CTA. This article noted that CTA was useful in both identifying the number of vessels involved in hemoptysis as well as identifying collateral vessels and shunts that increase the risk of complications during arterial embolization.

As discussed in the section above, approximately 10% of massive hemoptysis is due to a pulmonary arterial source, which can be occult on bronchial arteriography. Khalil et al [25] retrospectively reviewed 272 patients, 13 of whom had bleeding from a pulmonary artery origin. Of these 13 patients, 8 were initially and successfully treated with pulmonary artery embolization based on the CTA findings, and 3 more patients were subsequently imaged and successfully treated with pulmonary artery embolization after BAE failed to treat the hemoptysis. This study highlighted CTA guiding embolization therapy. A study by Shin et al [24] also documented the importance of detecting a pulmonary artery source of hemoptysis prior to embolization. In his study of 286 patients presenting with massive hemoptysis, they used CTA to identify 10 patients for a total of 11 PAPs as the source of the massive hemoptysis by CTA prior to undergoing BAE. Of these 11 PAPs, 6 PAPs detected on CTA could not be detected prospectively on conventional pulmonary arteriography, but CTA guided subselection pulmonary arteriography and resulted in successful embolization of the bleeding artery. The authors reported a pulmonary artery embolization success rate of over 90%. A subsequent study by Shin et al [26] also identified patients presenting with massive hemoptysis due to a pulmonary arterial source. Out of 712 patients with massive hemoptysis, 24 patients demonstrated PAPs on their preprocedural CTA examination. Fifteen of these PAPs identified on CTA were also visualized on pulmonary arteriography, all of which were successfully embolized. The remaining 9 PAPs identified on CTA were not detectable on conventional pulmonary arteriography and were subsequently treated with bronchial and systemic nonbronchial embolization, resulting in a 33% rate of hemoptysis cessation. Persistently symptomatic PAPs were subsequently treated by percutaneous or surgical interventions based on CTA findings.

There are no recent data comparing the diagnostic advantages between routine CT with IV contrast with CTA. However, CTA may offer a slight advantage over routine CT with IV contrast when the intention is to treat massive hemoptysis with BAE because CTA typically provides slightly better opacification of vessels, possibly improving detection of abnormal arteries potentially causing hemoptysis. At present, the vast majority of publications reporting BAE outcomes obtain CTA chest CTs prior to BAE for preprocedural planning.

Radiography Chest

Chest radiography has long been established as the initial imaging examination of choice given its portability, rapid acquisition, and interpretation time. Fartoukh et al [12], in a large retrospective study of 1,087 patients, correlated morbidity and mortality to findings on chest radiographs. However, there is discrepancy in the literature regarding the usefulness of radiographs in determining the etiology of hemoptysis.

In a study of 70 patients undergoing bronchial artery embolization for massive hemoptysis, causative radiologic abnormalities were seen in 86% of the chest radiographs [39]. This was similar to an earlier study showing 82% of chest radiographs could detect the side and predict the cause of bleeding [40]. However, in a comparable study of 80 patients with massive hemoptysis, chest radiographs demonstrated the cause of bleeding in only 35% of cases, most of whom had tuberculosis or malignancy [28]. Although radiography can be useful in directing treatment to the correct site of bleeding, a study of 20 patients undergoing BAE for massive hemoptysis showed that radiography localized the site of hemoptysis in only 35% of patients [41]. Similar findings were reported in a larger study of 348 patients, which included both massive and moderate recurrent hemoptysis patients [17]. Chest radiographs were performed in all patients and were abnormal in 313 patients (90%). However, these radiographs were suggestive of the etiology of hemoptysis in only 90 patients (26%).

These findings indicate that additional imaging in conjunction with chest radiograph is warranted in massive hemoptysis.

Variant 2: Nonmassive (non–life-threatening) hemoptysis. Initial imaging.

In the prior review, imaging recommendations were separated based on expectorated blood quantity, smoking history, and age above 40 years, which was based on several reviews demonstrating a higher prevalence of bronchogenic carcinoma compared with other etiologies in an older population with a positive smoking history [42-

44]. However, these prior variables excluded a significant portion of patients with nonmassive hemoptysis. In addition, imaging recommendations did not significantly differ between the two prior nonmassive hemoptysis variables. For these reasons, these risk factors have been removed, and there is a single nonmassive variable.

Arteriography Bronchial with Embolization

Conventional arteriography is not a primary modality for the diagnosis of nonmassive hemoptysis etiologies. However, arteriography with therapeutic BAE is increasingly utilized in nonmassive hemoptysis. The standard of care for nonmassive hemoptysis remains conservative medical therapy; however, in cases of palliation or failure of medical therapy—that is, when repeated episodes of nonmassive hemoptysis prevents patients from their normal daily activities—BAE is considered a viable and definitive therapeutic option.

Fujita et al [45] reported outcomes on palliative BAE for patients with lung cancer and hemoptysis. Of 28 patients with non–small-cell lung cancer presenting with varying degrees of hemoptysis, including almost a third of whom had nonmassive hemoptysis, 81% of patients had immediate hemoptysis cessation following BAE. The 2 patients who subsequently had mild recurrent hemoptysis after BAE were then successfully treated with conservative management.

Additional recent studies reporting BAE as a viable therapeutic option for nonmassive hemoptysis includes Dave et al [46], who reported BAE outcomes on 58 patients. In this study, 17% of the population presented with nonmassive hemoptysis, and the top two causes of hemoptysis were bronchiectasis and malignancy. The success rates proved to be similar between patients presenting with nonmassive versus massive hemoptysis. This study asserted that nonmassive hemoptysis might be the harbinger of future episodes of massive hemoptysis, especially in patients with underlying lung disease. These results justify BAE as a treatment of nonmassive hemoptysis. Woo et al [18] reported BAE outcomes on 406 patients, 30% of whom presented with nonmassive hemoptysis. This study also demonstrated similar success rates between patients with nonmassive versus massive hemoptysis. Shin et al [19] reported BAE outcomes on 163 patients, including 41% presenting with nonmassive hemoptysis; outcomes were not stratified by hemoptysis severity. Bhalla et al [15] reported similar post-BAE outcomes between patients presenting with nonmassive versus massive hemoptysis. Ishikawa et al [47] published the largest study on outcomes for nonmassive hemoptysis. Elective BAE was performed on 489 noncancer patients from Japan with varying degrees of nonemergent hemoptysis. They reported immediate bleeding cessation in 93% of patients, with 87% and 58% of patients remaining free of hemoptysis at 1 and 3 years, respectively. The most common causes of hemoptysis in this study were bronchiectasis (34%) and nontuberculous mycobacterium (24%).

Cryptogenic nonmassive hemoptysis has demonstrated a very high immediate and long-term success rate following BAE. In a retrospective study [48] reviewing 319 patients, 35 patients were identified as having cryptogenic hemoptysis, 23 of whom reported nonmassive hemoptysis. Thirty-three of the 35 patients with cryptogenic hemoptysis were successfully treated with BAE, and 97% of these patients remained free of hemoptysis at 20 months. The authors reported that there was no correlation between severity of hemoptysis and the diameter of the embolized bronchial artery. These results were not compared to the patients with a known cause of hemoptysis.

CT Chest with IV Contrast

As with massive hemoptysis, CT with IV contrast is the primary modality to determine hemoptysis etiology. Thirumaran et al [44], in an early study establishing CT as a diagnostic tool for nonmassive hemoptysis, retrospectively studied 270 patients with hemoptysis and a normal chest radiograph, with 94% reporting mild hemoptysis, and commonly with repeated episodes. Although the most common cause of hemoptysis was acute bronchitis (63%), the second most common cause was a respiratory tract neoplasm, the majority of which was a lung primary malignancy (n = 22/270). Lee et al [49] reported performing CT examinations on all 221 patients evaluated for hemoptysis, 48% with nonmassive hemoptysis and 52% with massive hemoptysis. Interestingly, both cohorts had similar etiologies, with bronchiectasis followed by active tuberculosis as the leading causes for hemoptysis, and CT proved to be the superior diagnostic imaging modality over bronchoscopy and arteriography for identifying the cause of hemoptysis.

CT with IV contrast is now the established imaging modality to determine the etiology of nonmassive hemoptysis, and therefore, there are no recent publications comparing its efficacy to other imaging modalities.

CT Chest without IV Contrast

As discussed in Variant 1, CT chest without IV contrast is only warranted in the diagnosis of hemoptysis in patients with poor renal function or life-threatening contrast allergy. The limited number of studies reviewing the utility of

CT chest without IV contrast for the evaluation of hemoptysis did not differentiate between massive versus nonmassive quantities of hemoptysis.

CT Chest without and with IV Contrast
Although very early publications studying the utility of CT in patients presenting with nonmassive hemoptysis performed chest protocols including acquisitions both without IV contrast followed by acquisitions with IV contrast, there are no data to support that there is any added value of CT chest without IV contrast prior to the administration of IV contrast in the diagnosis of nonmassive hemoptysis or in the preprocedural planning of BAE.

CTA Chest
There are no recent studies comparing the benefits of a routine chest CT with IV contrast to CTA in patients with nonmassive hemoptysis. As previously discussed, preprocedural CTA or routine CT with IV contrast has become the standard of care for arterial planning of BAE. In a recent study reporting the outcomes of BAE in patients with primarily nonmassive hemoptysis, all 489 noncancer patients underwent a CTA prior to embolization [47]. The authors noted that conventional aortography previously used to detect origins of the bleeding bronchial arteries was effectively replaced by arterial mapping information provided by CTA.

Radiography Chest
Chest radiographs continue to be a reasonable initial imaging choice in patients with nonmassive hemoptysis, especially when used to confirm a clinical diagnosis for benign disease such as acute bronchitis or pneumonia. There are no recent studies comparing the utility of chest radiographs with other imaging modalities.

Variant 3: Recurrent hemoptysis. Initial imaging.

Recurrent hemoptysis is a new variant for this update. It is defined as repeated episodes of hemoptysis following initial treatment with either medical therapy or BAE. Typically, the etiology of recurrent hemoptysis is known and usually not life threatening, although there is a wide range of hemoptysis severity. Recent literature shows a trend of more commonly treating patients with nonmassive recurrent hemoptysis with interventional or surgical procedures rather than conservative therapies compared with patients with an initial presentation of nonmassive hemoptysis. Therefore, imaging recommendations differ between patients initially presenting with nonmassive hemoptysis and patients presenting with recurrent nonmassive hemoptysis.

Arteriography Bronchial with Embolization
Recurrent hemoptysis is increasingly being treated with BAE after failure of medical therapy or failure of the initial BAE. Although recurrent hemoptysis within the first year occurs in approximately 20% to 30% of a general patient population following initial BAE [4,14,16,19,50-52], higher recurrent hemoptysis rates are associated with specific conditions, namely, chronic pulmonary aspergillomas [19,50,52-55], malignancy [19,46,52,56,57], and sarcoidosis [4]. The largest recent study investigating outcomes of BAE in patients with aspergillomas-causing hemoptysis was published by Shin et al [19]. They studied 64 patients with either chronic or simple aspergillomas, 77% of which developed in a pre-existing cavity from tuberculosis. This study documents a low immediate success rate of 64% and a high recurrence rate of 55% for this subset of patients. For this reason, the authors' recommendation for this population is definitive surgical treatment following initial intervention with BAE for acute massive hemoptysis [51]. BAE for malignancy is typically either palliative or performed as a temporizing measure prior to definitive surgery. Recurrent hemoptysis in patients with lung cancer is associated with a high mortality [52,56], which is attributed to the disease process rather than post-BAE procedural complications. BAE is also typically palliative in patients presenting with hemoptysis due to sarcoidosis because these patients usually have advanced pulmonary disease and are not surgical candidates. Pulmonary arterial shunting seen at arteriography for BAE is also consistently associated with an increased rate of hemoptysis recurrence.

Recurrent hemoptysis due to "technical failure," occurring within 3 months of the initial BAE, is most often caused by incomplete or missed embolization of bleeding arteries. When hemoptysis recurs after 3 months from the initial BAE, treatment failure is most likely due to vascular collateralization or recannulation [58]. Recent studies [4,46,50-55] have consistently shown no increased risk of morbidity or mortality for repeat BAE interventions following recurrent hemoptysis for either technical failure or vascular collateralization/recannulation. The exception to this conclusion was published by Vidal et al [59]. This group compared 30 patients with cystic fibrosis and massive hemoptysis requiring BAE with a control group of patients with cystic fibrosis who did not require BAE. The cohort that had BAE interventions for hemoptysis, commonly with multiple interventions, demonstrated a decline in forced expiratory volume, a decreased 5-year survival (31% versus 84%), and an increased rate of lung transplantation compared with the control group without hemoptysis. A confounding consideration in this study is whether these

outcomes were due to sequelae from BAE or sequelae from recurrent hemoptysis. Of the handful of studies documenting lack of clinically significant change following BAE, Tom et al [4] specifically studied long-term clinical parameters of patients prior to and following BAE. Of the 69 patients with hemoptysis initially treated with BAE, 17 patients had at least 5 years of clinical data before and 5 years of clinical data after the initial BAE. The authors identified that pulmonary function parameters declined at the same rate prior to the initial BAE as they had following BAE.

CT Chest with IV Contrast
Patients with recurrent hemoptysis typically have a known cause. Bronchiectasis due to repeated or indolent infection is the most common cause for recurrent hemoptysis in most large studies. In patients with cystic fibrosis, for example, recurrent hemoptysis may be an indicator of acute infection [60], and CT may not be indicated. There are limited data evaluating the utility of CT chest with IV contrast in the setting of a known cause of hemoptysis.

CT Chest without IV Contrast
There is no relevant literature supporting the use of CT chest without IV contrast in the assessment of recurrent hemoptysis.

CT Chest without and with IV Contrast
There is no relevant literature supporting the use of CT chest without IV contrast prior to a CT performed with IV contrast in patients with recurrent hemoptysis.

CTA Chest
There are no recent data comparing the diagnostic advantages between routine CT with IV contrast with CTA in patients with recurrent hemoptysis. However, a recent publication studied the potential benefit of CTA for preprocedural planning for BAE in patients with recurrent hemoptysis. Zhao et al [61] reported retrospective data on 15 patients who had developed recurrent hemoptysis out of the 135 patients treated with BAE over a 2-year interval. BAE resulted in recurrent hemoptysis within 24 hours in 65% of the arteries initially embolized, arteries that were selected based on their abnormal appearance at conventional arteriography. CTA chest studies performed after the initial embolization in these patients successfully identified 16 additional suspected bleeding arteries, which subsequently were embolized and resulted in complete hemoptysis cessation. This article suggests that CTA provides improved sensitivity in the identification of arteries causing hemoptysis over conventional arteriography in patients with recurrent hemoptysis.

Radiography Chest
There is no relevant literature supporting the use of chest radiographs in patients with recurrent hemoptysis. However, chest radiography remains clinically relevant in potentially detecting an acute, commonly infectious cause that can be treated by noninvasive therapies.

Summary of Recommendations

Variant 1: Arteriography bronchial with embolization, CT chest with IV contrast, CTA chest with IV contrast, and chest radiographs are usually appropriate for the initial imaging of patients with massive life-threatening hemoptysis. For clarification, either CT chest with IV contrast or CTA chest with IV contrast would be appropriate but not both in tandem. Bronchial embolization, CT chest with IV contrast, and chest radiographs are complementary (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient's care).

Variant 2: Chest radiography and either CT chest with IV contrast or CTA chest with IV contrast is usually appropriate for the initial imaging of patients with nonmassive non–life-threatening hemoptysis. CT chest with IV contrast and CTA chest with IV contrast are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

Variant 3: Chest radiography and CTA with IV contrast are usually appropriate in the initial imaging of patients with recurrent hemoptysis. Arteriography bronchial with embolization is also usually appropriate for the initial imaging of patients with recurrent threatening hemoptysis. These imaging procedures are complementary (ie, more than one procedure is ordered as a set or simultaneously in which each procedure provides unique clinical information to effectively manage the patient's care).

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document [62].

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."		

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The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.