

Multidetector CT of bronchial and non-bronchial systemic arteries

Adalet Elçin Yıldız, Orhan Macit Arıyürek, Erhan Akpınar, Bora Peynircioğlu, Barbaros Erhan Çil

ABSTRACT

We evaluate the use of multidetector row computed tomography (MDCT) angiography for the depiction of bronchial and non-bronchial systemic arteries (NBSAs), which frequently become enlarged as a secondary finding in a wide array of chronic lung diseases and other diseases that affect the pulmonary vascular system. MDCT angiography has enabled radiologists to provide thin-slice axial images, multi-planar reconstructions, interactive maximum intensity projections, and volume-rendered images to evaluate the origin and course of the abnormal bronchial arteries and enlarged NBSAs that may be the cause of hemoptysis. Embolization of the bronchial arteries is the primary treatment option in patients with massive hemoptysis. Precise localization of the bleeding vessel(s) prior to catheter arteriography not only is the most important factor for prompt and successful embolization but also prevents the recurrence of hemoptysis from missed NBSAs during procedures.

Key words: • computed tomography, X-ray • hemoptysis
• bronchial arteries

The lungs have one of the largest blood supplies in the human body. Their rich circulation is supplied via two separate vascular systems: the pulmonary and bronchial arteries. The pulmonary arteries are the most important component of these systems and provide 99% of the arterial blood to the lungs for gas exchange. Bronchial arteries primarily deliver blood to the trachea, extra- and intrapulmonary airways, bronchovascular bundles, nerves, supporting structures, regional lymph nodes, visceral pleura, esophagus, the vasa vasorum of the aorta, and pulmonary arteries and veins. Pulmonary and bronchial arteries have rich and complex anastomoses at the capillary level (1, 2).

The non-bronchial systemic arterial supply to the lungs should be considered in cases of pleural thickening greater than 3 mm, as should the enlarged and tortuous enhancing arteries within the extrapleural fat that result from parenchymal lung disease. These anatomical changes are considered to be the result of reduced pulmonary arterial perfusion and chronic inflammation (1, 3, 4).

The computed tomography (CT) depiction of bronchial and NBSAs is primarily influenced by the size and course of these arteries and the technique used to scan the lungs. Enlarged bronchial arteries can easily be visualized as nodular or tubular structures within the mediastinum, around the central airways, or within the extrapleural fat planes on contrast-enhanced CT images (2, 4, 5).

Several diseases that affect the pulmonary vascular system may give rise to enlarged bronchial and NBSAs that are primarily caused by chronic thromboembolic disease and vasculitic connective tissue diseases (Figs. 1 and 2). However, chronic inflammatory problems of the lung parenchyma and airways, for example, bronchiectasis (Figs. 3–8), chronic bronchitis, tuberculosis, and chronic fungal infections, can also be underlying disorders. Furthermore, malignant diseases of the lungs are also possible culprit lesions that result in the same clinical picture. The aforementioned chronic inflammatory diseases may also affect the pleural surfaces and cause hypertrophic and tortuous NBSAs within the extrapleural fat (1–4).

The most important and potentially catastrophic clinical outcome of these enlarged vessels is rupture which leads to hemoptysis. Rupture is usually caused by elevated regional blood pressures or vessel wall erosion by bacterial pathogens. In such patients, multidetector (MDCT) angiography is an important potential diagnostic modality for the accurate and prompt diagnosis of the underlying vascular disorder because it provides a map of these vascular structures. The mapping and the depiction of these vessels are of utmost importance for an effective pretreatment, mainly before embolization of the bronchial arteries, in work up of severely affected patients unresponsive to supportive and conservative measures (4).

From the Department of Radiology (A.E.Y. ✉ aelcindr@gmail.com), Hacettepe University School of Medicine, Ankara, Turkey.

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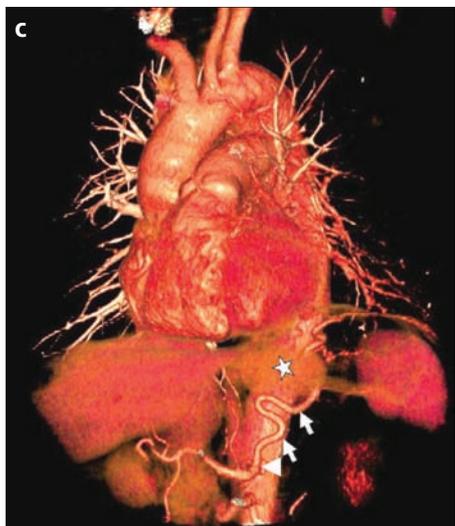


Figure 1. a–c. Non-bronchial systemic arterial supply from the left internal mammary artery and left inferior phrenic artery in a 63-year-old woman with Behçet disease. Volume-rendered image (a) shows an enlarged and tortuous branch (arrows) of the left internal mammary artery (arrowhead) within the extrapleural fat. Axial thin-slab maximum-intensity-projection (MIP) reconstruction (b, mediastinal window) shows an enlarged and tortuous left inferior phrenic artery (arrows). Volume-rendered image shows (c) an enlarged and tortuous left inferior phrenic artery (arrows) arising from the celiac trunk (arrowhead). In addition, note the diaphragm (star).

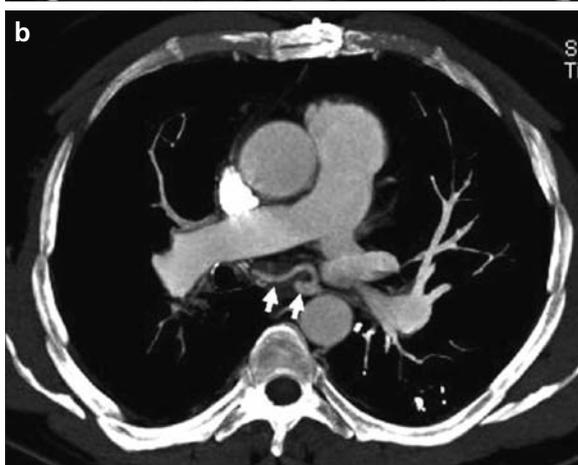
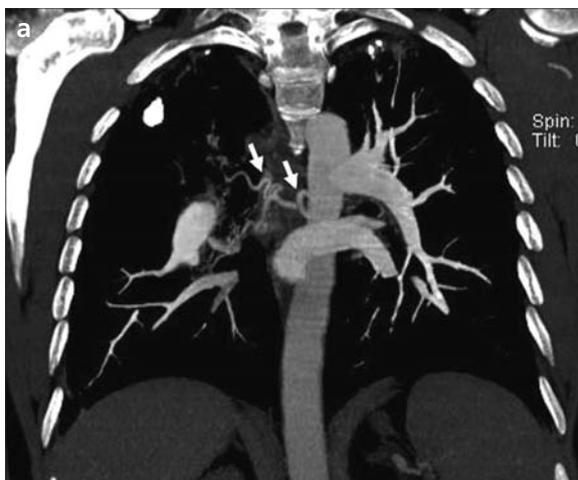


Figure 2. a, b. An enlarged, orthotopic right bronchial artery in a 56-year-old man with pulmonary thromboemboli, for which he underwent pulmonary endarterectomy. Coronal and axial thin-slab MIP reconstruction images (a, b, mediastinal window) show an enlarged and tortuous orthotopic right bronchial artery (arrows).

Anatomy of bronchial arteries

An in-depth and precise knowledge of the anatomy of the bronchial arteries is the most important step for correct diagnosis and treatment. These arteries most commonly arise directly from the descending aorta at the T5 and T6 levels of the vertebral bodies and are, therefore, referred to as orthotopic. When bronchial arteries originate from the descending aorta at different levels or from the aortic branches, they are referred to as ectopic or aberrant. Both orthotopic and ectopic bronchial arteries enter the lung parenchyma through the hilum and course parallel to the main bronchi and their branches (4, 6).

Regarding orthotopic bronchial arteries, Cauldwell et al. have reported four classic branching patterns: (a) type 1, two bronchial arteries on the left and one on the right, which present as an intercostobronchial trunk (ICBT) (40.6%);

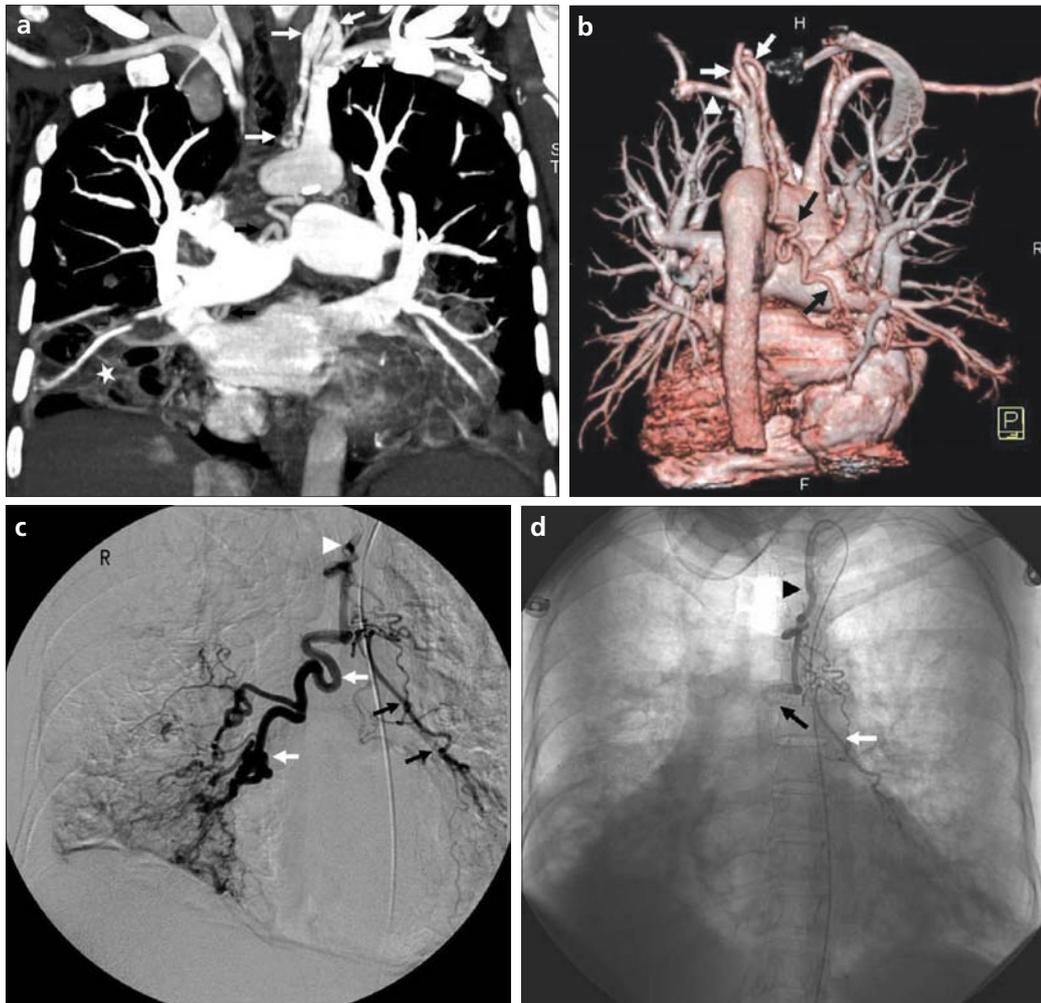


Figure 3. a–d. An enlarged ectopic right bronchial artery in a 52-year-old woman with bronchiectasis and recurrent hemoptysis. Coronal thin-slab MIP reconstruction (**a**, mediastinal window) shows an enlarged and tortuous ectopic right bronchial artery (*black arrows*) arising from the thyrocervical trunk (*white arrows*) that originates from the left subclavian artery (*arrowhead*). In addition, note the bronchiectasis in the right lower lobe (*star*). Volume-rendered image (**b**) shows an enlarged and tortuous ectopic right bronchial artery (*black arrows*) as well as the thyrocervical trunk (*white arrows*) and its origin from the left subclavian artery (*arrowhead*). Selective transcatheter thyrocervical trunk injection (**c**, *arrowhead*) shows an enlarged and tortuous ectopic right bronchial artery (*white arrows*) as well as an ectopic left bronchial artery (*black arrows*). Selective injection of the thyrocervical trunk (**d**, *arrowhead*) after superselective embolization of the right branch with two vials of polyvinyl alcohol particles shows a complete occlusion of the embolized artery (*black arrow*) with a preservation of flow in the left branch (*white arrow*).

(b) type 2, one on the left and one ICBT on the right (21%); (c) type 3, two on the left and two on the right (one ICBT and one bronchial artery) (20%); and (d) type 4, one on the left and two on the right (one ICBT and one bronchial artery) (9.7%) (Fig. 9) (7). The left bronchial artery usually arises from the anterior aspect of the descending thoracic aorta and courses toward the left hilum. On the right, an ICBT usually arises from the right posteromedial aspect of the thoracic aorta and courses cranially before branching into the intercostal artery (or arteries) and the right bronchial artery. Next, it caudally and sharply turns and then proceeds to the level of the right main bronchus (4, 7).

The most frequent sites of origin of the ectopic bronchial arteries have been reported as follows: the concavity of the aortic arch, the ipsilateral or contralateral subclavian artery, the descending aorta, the ipsilateral brachiocephalic trunk, the ipsilateral internal mammary

artery, and the ipsilateral thyrocervical trunk (Fig. 3 and Table 1) (6).

In adults, the normal diameter of bronchial arteries is less than 1.5 mm at their origin and 0.5 mm at the point of entry into the bronchopulmonary segment. Arteries that are 2 mm and larger in diameter on a CT scan are considered to be abnormal (1, 4).

The most common locations of enlarged bronchial arteries on a CT scan

are the retroesophageal, retrotracheal, and retrobronchial areas as well as the posterior wall of the main bronchus and the aorticopulmonary window (Figs. 2, 4, 5, and 7). The primary pitfalls of CT scanning include mediastinal lymph nodes, the azygos vein, and an enhancing esophageal wall, all of which cause diagnostic confusion by mimicking the bronchial arteries (2, 4, 5).

Table 1. The most frequent sites of origin of the ectopic bronchial arteries

Concavity of the aortic arch (74%)
Ipsilateral and contralateral subclavian artery (10.5%)
Descending aorta (8.5%)
Ipsilateral brachiocephalic trunk (2%)
Ipsilateral internal mammary artery (2.5%)
Ipsilateral thyrocervical trunk (2.5%)



Figure 4. a–c. An enlarged orthotopic left bronchial artery in an 82-year-old woman with cystic bronchiectasis and hemoptysis. Axial 2-mm-thick slice CT image (**a**, lung window) shows cystic bronchiectasis in the left lung (*arrows*). Axial 2-mm-thick slice CT image (**b**, mediastinal window), which was obtained at the level of the carina, depicts an enlarged orthotopic left bronchial artery (*arrow*) arising from the descending aorta (*arrowhead*). Axial 2-mm-thick slice CT image (**c**, mediastinal window), which was obtained at the level of right pulmonary artery, depicts a tubular hypertrophied orthotopic left bronchial artery (*arrows*) along the posterior wall of the left main bronchus (*star*).

Patients with pulmonary vascular diseases (i.e., chronic thromboembolic disease or vasculitic disorders) experience a reduced pulmonary arterial blood flow to the lungs, which subsequently leads to the proliferation of bronchial arteries and the replacement of formal pulmo-

nary arterial circulation. In chronic inflammatory lung diseases, the release of angiogenic growth factors leads to the neo-vascularization and remodeling of the bronchial and NBSAs. Neoplastic diseases also cause tumor-mediated neo-vascularization (1, 4).

Table 2. The most frequent sites of origin of the non-bronchial systemic arteries

Brachiocephalic trunk
Subclavian arteries
Thyrocervical and costocervical trunks
Axillary arteries
Internal mammary arteries
Inferior phrenic arteries
Gastric arteries
Celiac axis

Anatomy of NBSAs

NBSAs and bronchial arteries are differentiated by their courses. NBSAs enter the pulmonary parenchyma through adherent pleura or via the pulmonary ligament, and their course is not parallel to the bronchi. NBSAs can arise from the branches of the supraaortic great vessels, such as the brachiocephalic trunk and subclavian arteries (Fig. 8), or from the thyrocervical and costocervical trunks. Other sites of origin for NBSAs include the axillary arteries, internal mammary arteries (Figs. 1, 5, and 6), and infradiaphragmatic aortic branches, such as inferior phrenic arteries (Fig. 1), gastric arteries, and the celiac axis. Non-bronchial systemic arterial supply to the lung must be kept in mind when the pleural thickness is greater than 3 mm and when enlarged and tortuous enhancing arteries are detected within the extrapleural fat (Figs. 1, 5, 6, 7, and 8, and Table 2) (1, 3, 4).

MDCT techniques

For the imaging of bronchial and NBSAs, CT imaging should be acquired from the supraclavicular area to the level of the ostia of the renal arteries, including the supraaortic great vessels and the infradiaphragmatic arteries, which may also supply collateral

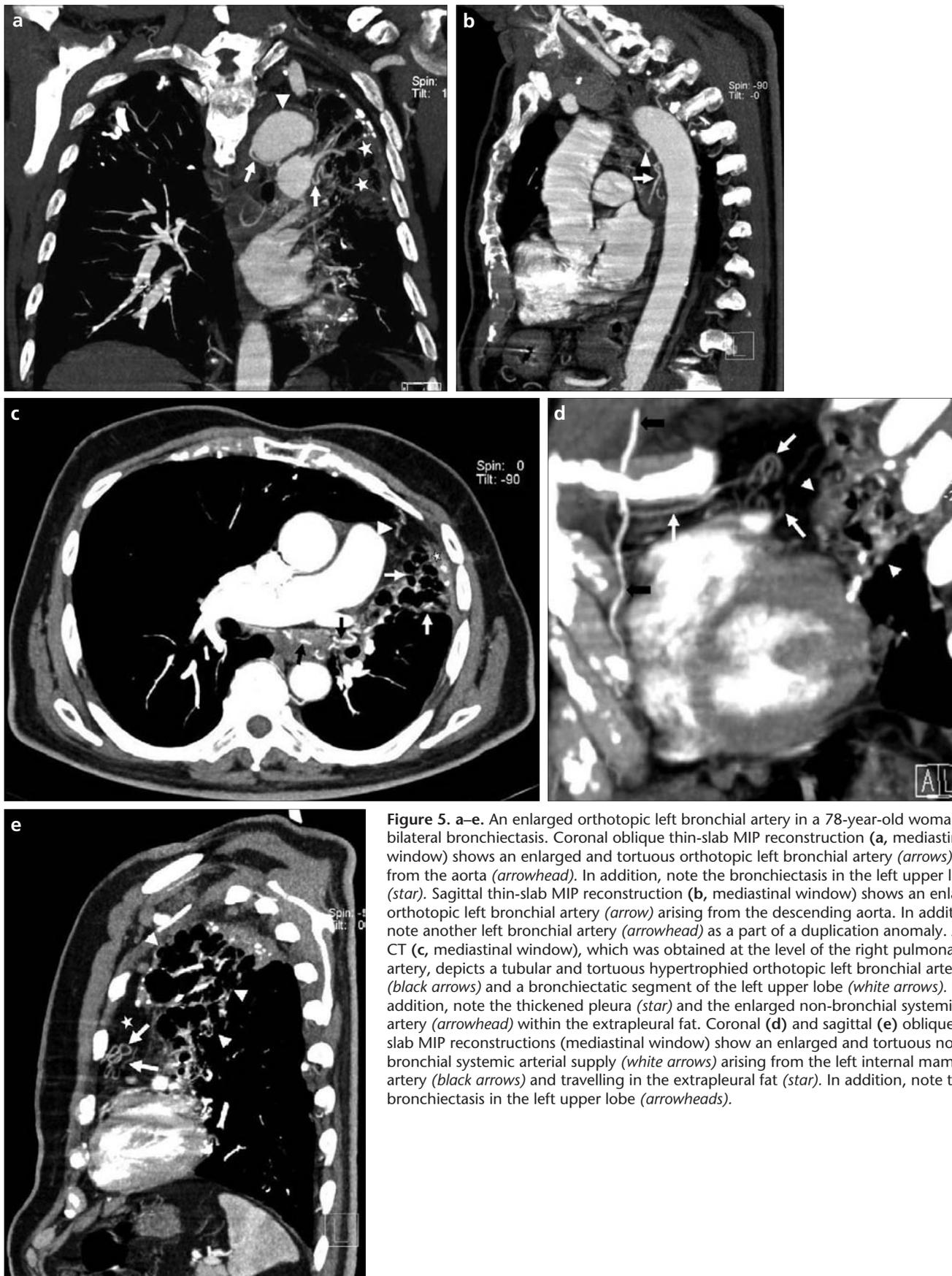


Figure 5. a–e. An enlarged orthotopic left bronchial artery in a 78-year-old woman with bilateral bronchiectasis. Coronal oblique thin-slab MIP reconstruction (**a**, mediastinal window) shows an enlarged and tortuous orthotopic left bronchial artery (*arrows*) arising from the aorta (*arrowhead*). In addition, note the bronchiectasis in the left upper lobe (*star*). Sagittal thin-slab MIP reconstruction (**b**, mediastinal window) shows an enlarged orthotopic left bronchial artery (*arrow*) arising from the descending aorta. In addition, note another left bronchial artery (*arrowhead*) as a part of a duplication anomaly. Axial CT (**c**, mediastinal window), which was obtained at the level of the right pulmonary artery, depicts a tubular and tortuous hypertrophied orthotopic left bronchial artery (*black arrows*) and a bronchiectatic segment of the left upper lobe (*white arrows*). In addition, note the thickened pleura (*star*) and the enlarged non-bronchial systemic artery (*arrowhead*) within the extrapleural fat. Coronal (**d**) and sagittal (**e**) oblique thin-slab MIP reconstructions (mediastinal window) show an enlarged and tortuous non-bronchial systemic arterial supply (*white arrows*) arising from the left internal mammaryian artery (*black arrows*) and travelling in the extrapleural fat (*star*). In addition, note the bronchiectasis in the left upper lobe (*arrowheads*).

branches to the lungs. With current multidetector row systems, optimal enhancement of both the pulmonary and systemic arteries can be achieved with the injection of approximately 100–120 mL of a high-density, non-ionic contrast medium (300–350 mg/dL) with an automated injector at a rate of 3–4 mL/s via an antecubital vein. A region of interest should be placed at the pulmonary artery, and as the threshold value of 120 HU is approached, cranio-caudal scanning should be started six seconds later with the patient in the supine position and holding one deep inspiration. Furthermore, technical parameters change from one scanner to another. In our institution, we use 16 and 64 MDCT scanners (Sensation, Siemens Medical Solutions, Erlangen, Germany), a beam width of 10 mm, a beam pitch of 1.3–1.5, and a reconstruction thickness of 1.0–1.25 mm at 80–120 kV and 90–140 mA (1, 8, 9).

Post-processing of the raw data is performed with axial thin-section images, multiplanar reconstruction, interactive maximum intensity projection, and volume-rendered techniques in order to optimally evaluate the origins and courses of the bronchial and NBSAs.

Transcatheter embolization

The endovascular treatment of massive hemoptysis is a well-established technique. Selective catheterization and embolization of abnormal bronchial arteries or NBSAs (e.g., using particles, gelfoam, n-butyl cyanoacrylate) is generally the first-line treatment (Fig. 3). Anatomical variations in the bronchial arterial tree may cause technical difficulties in superselective catheterization for safe embolization. Potential complications of the procedure include non-target embolization, depending on the selected arteries (e.g., spinal arteries, aorta). Therefore, several other bronchial artery anastomoses (e.g., the coronary artery) should be sought prior to the administration of embolic agents in order to prevent potentially catastrophic complications (10). Additional embolizations may be needed in the case of extensive lung pathologies that cause additional systemic collateral supply during the intervals. Surgical lobectomy is another treatment option and may be indicated in patients who exhibit recurrent, persistent, and massive hemoptysis and who have not responded to repeated transcatheter embolizations.

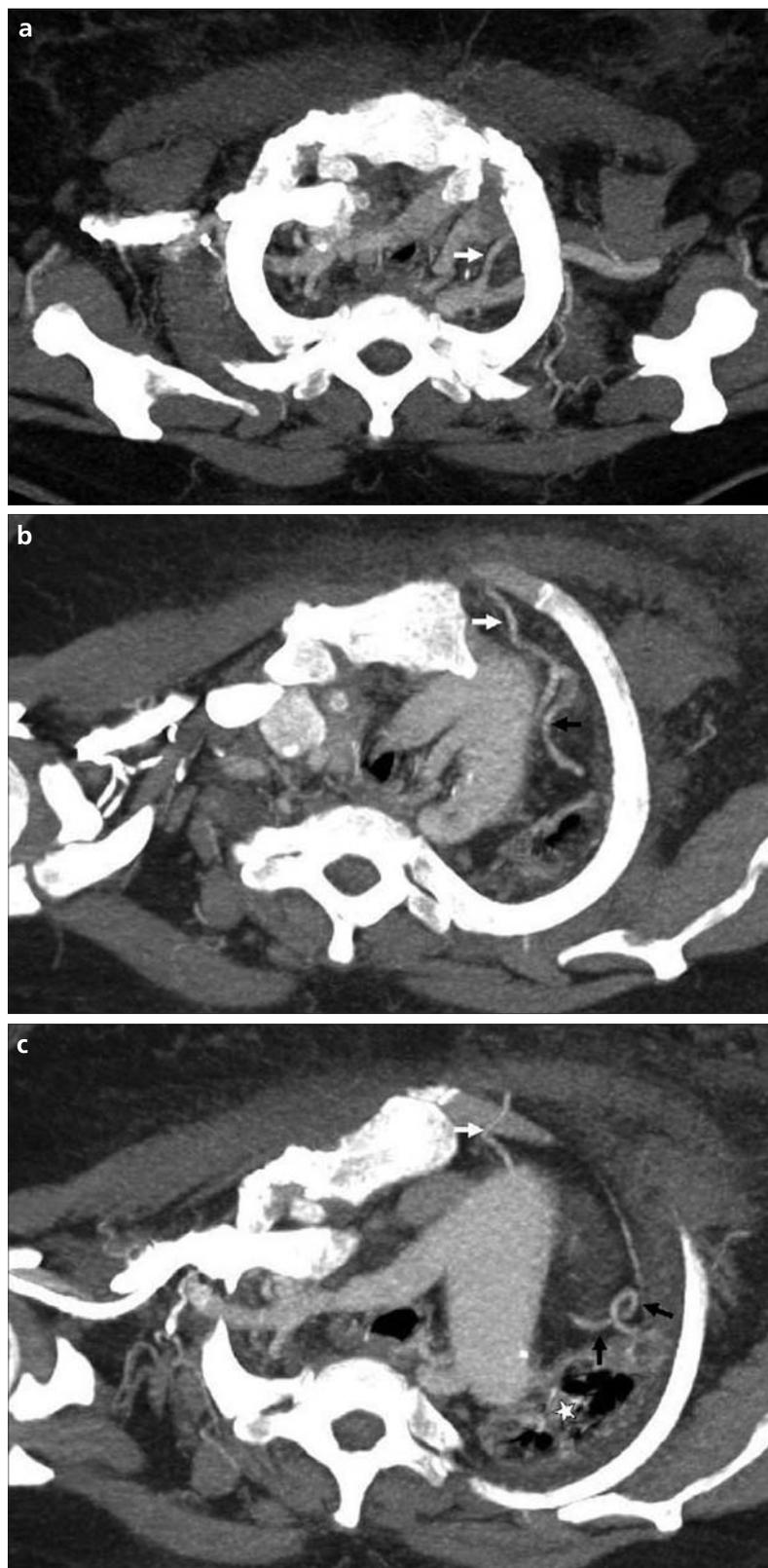


Figure 6. a–c. A non-bronchial systemic artery arising from the left internal mammary artery in a 57-year-old man with cystic bronchiectasis. Axial oblique thin-slab MIP reconstructions (mediastinal window) depict an enlarged and tortuous branch (*black arrows*) of the left internal mammary artery (*white arrow*) that courses in the extrapleural fat. In addition, note the bronchiectasis in the left lung (*star*).



Figure 7. An enlarged orthotopic right bronchial artery and non-bronchial systemic arteries arising from intercostal arteries in an 83-year-old man with bilateral bronchiectasis. Coronal oblique thin-slab MIP reconstruction (mediastinal window) shows an enlarged right intercostobronchial artery (*black arrows*) and its branches, an orthotopic right bronchial artery (*white arrowhead*), and an intercostal branch (*white arrows*). In addition, note the bilateral bronchiectasis (*black arrowhead*), thickened pleura (*stars*), and enlarged and tortuous branches arising from the intercostal arteries (*white arrows*) within the extrapleural fat.

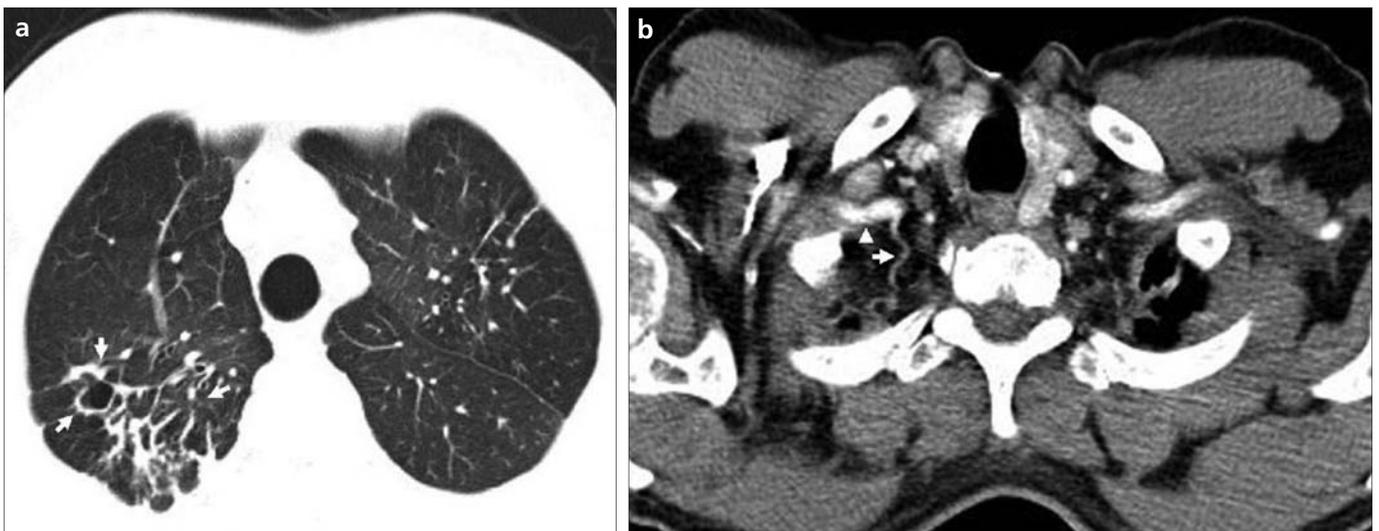


Figure 8. a, b. Non-bronchial systemic arterial supply arising from the right subclavian artery in a 53-year-old man with right upper lobe bronchiectasis. Axial CT image (**a**, lung window) depicts right upper lobe bronchiectasis (*arrows*). Axial CT image (**b**, mediastinal window) depicts an enlarged branch (*arrow*) arising from the right subclavian artery (*arrowhead*) as a non-bronchial systemic artery.

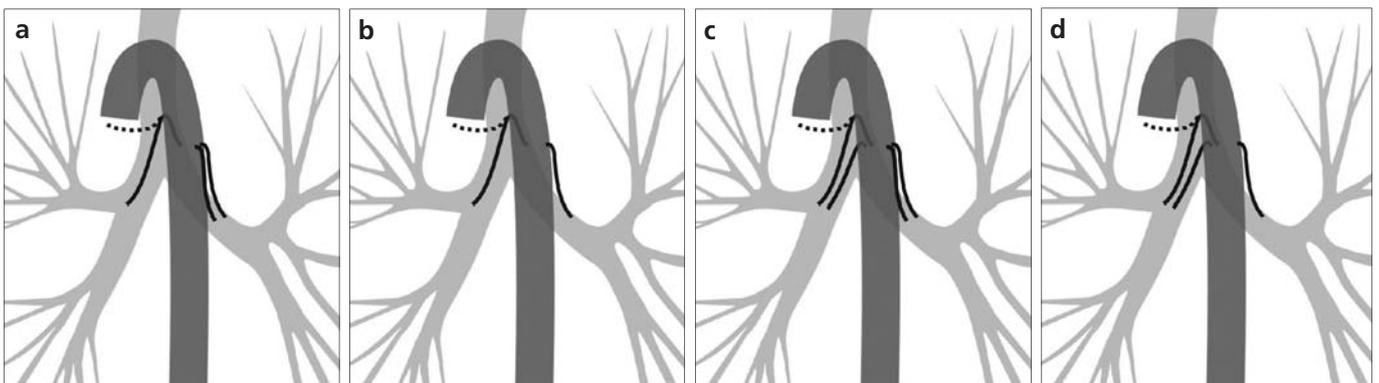


Figure 9. a–d. Diagrams that illustrate the types of orthotopic bronchial arterial supply. Type 1 (**a**), two bronchial arteries on the left and one bronchial artery on the right that present as an intercostobronchial trunk (ICBT) (40.6%). Type 2 (**b**), one bronchial artery on the left and one ICBT on the right (21%). Type 3 (**c**), two bronchial arteries on the left and two bronchial arteries on the right (one ICBT and one bronchial artery) (20%). Type 4 (**d**), one bronchial artery on the left and two bronchial arteries on the right (one ICBT and one bronchial artery) (9.7%).

Conclusion

Precisely outlining bronchial vascularization and detecting anatomical variations to enable careful treatment planning may be useful in the case of hemoptysis and related conditions. Even if the patient is not suffering from hemoptysis at the time of the CT examination, precise vascular mapping may prevent time-consuming studies prior to radiological and surgical interventions that intend to prevent future episodes of hemoptysis.

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