ORIGINAL ARTICLE

Utility of multidetector row computed tomography in the management of hemoptysis: An experience from Upper Egypt

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Abstract *Background:* We aimed to report our experience with the use of multidetector row computed tomography (MDCT), with angiography in the evaluation of patients with hemoptysis.

Methods: A prospective study was carried out on 52 patients suffering from hemoptysis, from May 2011 to August 2014. They underwent MDCT using a 16-detector row scanner with bronchial and pulmonary angiographic techniques.

Results: MDCT identified the cause of hemoptysis in 92% of patients. MDCT angiography was able to detect the site and vascular source of bleeding in 85% of patients. A total of 92 bronchial arteries were detected in 65% of patients; 29 of these arteries (31%) were abnormally dilated.

Conclusion: Our results confirm that MDCT angiography is a useful method to identify and depict the bronchial arteries and to predict the presence of nonbronchial systemic vessels that supply a parenchymal lesion. MDCT angiography allows a rapid and detailed identification of abnormal vasculature and provides a precise road map which can be used to guide therapeutic arterial embolization.

Introduction

Hemoptysis is defined as bleeding arising from the lower airways [1]. Identifying the etiology of hemoptysis and classifying it in terms of the amount of blood expectorated as well as the rate of bleeding play a fundamental role in defining the timing, way and place of managing a patient with hemoptysis [2].

There are multiple causes of hemoptysis, including airway diseases, parenchymal lung diseases, cardiovascular diseases, and others [3]. However, no cause is identified in 15–30% of all cases, and is termed idiopathic or cryptogenic hemoptysis [4]. In the majority of cases, the source of massive hemoptysis is the bronchial circulation. However, nonbronchial systemic arteries can be also a significant source [5].

Imaging modalities pertinent to the evaluation of hemoptysis include chest radiography, computed tomography (CT), and bronchial arteriography.

Conditions such as bronchiectasis, chronic bronchitis, lung malignancy, tuberculosis, and chronic fungal infection are easily detected with conventional CT [6]. Even, 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 [4].

However, more recently, the development of multidetector row CT (MDCT) has provided a comprehensive, noninvasive method of evaluating the entire thorax [1,7]. At the same time, the combined use of thin-section axial scans and more complex reformatted images allows clear depiction of the origins and trajectories of abnormally dilated bronchial or non-bronchial systemic arteries that may be the source of hemorrhage requiring embolization [5,7].

Assiut University Hospital is a tertiary referral center, where many patients, from all over Upper Egypt, are referred for the evaluation and management of hemoptysis. Therefore, in the current study, we aimed to report our experience with the use of MDCT, especially with its new applications such as reformatted images, high resolution imaging and post-processing techniques, in the management of patients with hemoptysis. We aimed also to determine the additional benefit of MDCT angiographic technique in identifying the site of bleeding and its vascular origin.

Patients and methods

Patients

This prospective study was carried out on 52 patients suffering from hemoptysis, enrolled from May 2011 to August 2014. These patients included those admitted to the Department of Chest Diseases, Assiut University Hospital, and those patients with known lung cancer who presented with hemoptysis during their admission or outpatient follow up at the Department of Medical Oncology, South Egypt Cancer Institute (SECI). All patients were subjected to complete clinical assessment. A detailed history was obtained.

The volume of hemoptysis corresponds to the cumulated amount of bleeding, which was assessed from the onset of bleeding until time of CT examination using a standardized scale: spoonful (5 mL), small filled glass (100 mL), and large filled glass (200 mL). According to the severity of hemoptysis, it was classified as "mild" (< 30 mL), "moderate" (30–600 mL), "severe" or "massive" (> 600 mL) [8].

Exclusion criteria included (1) pregnant females. (2) Patients with chronic renal failure (or impairment) not on regular dialysis. (3) Patients who are hemodynamically unstable. (4) Severe cardiac disease causing orthopnea. (5) Sensitivity to the contrast medium. (6) Patients with life-threatening hemoptysis till been stabilized.

Full clinical examination was carried out. Laboratory data were reviewed particularly for platelet count and coagulation profile.

All enrolled patients were subjected to plain chest X-ray and MDCT for assessment of the integrity of pulmonary and/or systemic circulation.

Fiberoptic bronchoscopy (FOB) with histopathologic examination was carried out in some selected patients (suspected lung cancer, unresolved pneumonia). Digital subtraction angiography (DSA) was carried out in those patients planned to undergo embolization procedure.

The study was approved by the local ethics committee of both the health care facilities and a written consent was obtained from all patients who participated in the study.

Multidetector CT

Patient preparation

All patients were instructed to fast 6 h prior to the examination. All steps of the study were explained in detail for each patient. An IV access was secured (an 18 G cannula).

Scan protocol

A 16-detector row scanner General Electric (Light Speed Ultra 16; GE Medical Systems) was used. Pre & post contrast CT studies were performed in all patients. CT imaging was performed with patients in the supine position at maximal inspiration during a single breath hold.

Acquisition

First, a scout view of the thorax is used to plan CT data acquisition. A 28–33 cm field of view, 512×512 matrix size, and a collimation of 1.25 mm and 1.5–2 pitch were used. The mean acquisition time was 12–18 s. By adjusting the exposure parameters, kilovoltage (100–140) and milliampere-seconds (90–140) according to the patients' weight the radiation dose to the patient can be minimized without composing image quality.

The MDCT bronchial angiographic technique

CT imaging had been acquired from the supraclavicular area to the level of the ostia of the renal arteries, including the supraaortic great vessels and the infra-diaphragmatic arteries, which may also supply collateral branches to the lungs. Optimal enhancement of both the pulmonary and systemic arteries was achieved with the injection of 120 mL of a high-density, low osmolar non-ionic contrast medium (350 mg/dL) with an automated injector at a rate of 4 mL/s via an antecubital vein. The automatic bolus triggering software program was also systematically applied, with a circular region of interest positioned at the descending aorta at the level of carina, and as the threshold value of 100 HU was approached, craniocaudal

scanning started. Thoracic CT angiography with a combination of selected reformatted images is done. Assessment of the lung parenchyma and airways as well as the mediastinum was always done as in routine CT chest studies, using both lung parenchyma and mediastinal window settings.

Post processing techniques

Post-processing of the raw data was performed with axial thin section images, multiplanner reformation (MPR), interactive maximum intensity projection (MIP), and volume-rendered (VR) techniques in order to optimally evaluate the origins and courses of the bronchial and non-bronchial systemic arteries (NBSAs).

Data interpretation for routine CT chest

CT was analyzed to look for the cause of hemoptysis and to localize the site of hemoptysis. Images were viewed in the lung and mediastinal window to look for parenchymal changes, any lymphadenopathy, pleural thickening, and major vessels.

Analysis of bronchial arteries

CT interpretation was done by using axial images, multiplanar reformation images, and 3-dimensional reconstructions (MIP and VR) images to identify bronchial arteries, and the following parameters were recorded:(1) the total number of bronchial arteries per side; (2) the site of the ostium of the bronchial artery (or arteries); (3) location of the ostium on the wall of the descending aorta (ie, posterior, medial, anterior, or lateral), and its position relative to the tracheal carina, (4) bronchial artery diameter; (5) visualized course of bronchial arteries.

Bronchial arteries were considered abnormal when (a) the diameter of the bronchial artery was $\geqslant 2$ mm, or (b) the course of the bronchial artery was visualized up to the hilum. The bronchial artery that satisfied either or both of these criteria was considered an abnormal hypertrophied artery and as a source of hemoptysis.

The origin of bronchial artery was considered orthotopic when the origin was from the descending aorta between the levels of the T5 and T6 vertebrae and ectopic when identified at a level of the descending aorta other than the expected origin (ie, outside levels T5–T6) or from any aortic branch vessel.

Analyses of non-bronchial systemic arteries

Arteries that enter the lung parenchyma through the inferior pulmonary ligament or through the adherent pleura and with trajectories that are not parallel to the bronchi are considered as non-bronchial arteries. They were considered abnormal when they become dilated and tortuous, and were seen within extrapleural fat in association with pleural thickening ($\geqslant 3$ mm) and/or lung parenchyma abnormalities. Whenever an abnormal nonbronchial systemic artery was identified, its origin and course were noted.

Digital subtraction angiography (DSA)

DSA was carried out in those patients for whom embolization procedure was anticipated. DSA was performed within a median period of 5 days (range, 1–20 days) after CT, depending upon the clinical condition of the patient; where 70–120 mL of nonionic (iohexol [Omnipaque; GE Healthcare, Princeton, NJ]) contrast agent was used. Angiographic procedures were performed with the knowledge of CT findings. For selective bronchial engagement, 5F/4F curved catheters such as the Simmons, celiac, picard, and renal double curve were used, and microcatheters were used when required. Arteriography also was done for nonbronchial systemic arteries when required.

The following angiographic findings were considered to be predictive of the vessels responsible for hemoptysis: (a) tortuous enlargement of bronchial and/or nonbronchial systemic arteries that supplied the area of parenchymal staining, and (b) a shunt into pulmonary vessels. The results of angiography were compared with the results of MDCT.

Statistical analysis

Data were analyzed using the Statistical Product and Service Solutions (Windows version 16.0; SPSS Inc. Chicago, USA).

Results

Fifty-two patients were prospectively enrolled into the current study. They included 41 (79%) patients admitted to the Department of Chest Diseases, Assiut University Hospital, and 11 (21%) patients with known LC admitted to the SECI. The patients included 37 (71%) males and 15 (29%) females with a mean age of 50 years (range from 20 to 75). Twelve (23%) and 34 (65%) patients had mild and moderate hemoptysis, respectively while 6 (12%) patients were reported to have severe hemoptysis.

The cause of hemoptysis was primarily diagnosed from the patient's history, physical examination and chest radiography. Final diagnosis was established by applying all clinical, laboratory, radiographic, MDCT, bronchoscopic, conventional angiographic findings and histopathology (if done). The most encountered cause of hemoptysis in our cohort was lung cancer, in 24 (46%) patients; followed by TB sequelae and bronchiectasis, in 11 (21%) and 6 (11.5%) patients, respectively. Table 1 shows the patient demographics and the grades and etiology of hemoptysis.

Chest X ray was done in all patients. Many radiographic findings have been identified, including mass in 11(21%), localized patch of consolidation in 2 (4%), bronchiectasis in 3 (5.5%), and cavitary lesion in 4 (7.5%) patients, respectively. Overall, plain radiography was considered successfully contributing in identification of the cause of hemoptysis in only 20/52 patients (38%). Fiberoptic bronchoscopy was carried out in 10 (19%) patients. It revealed the cause of bleeding in 8 (80%) patients, 6 patients had central bronchogenic carcinoma (proved by histopathological confirmation), and 2 patients had focal endobronchial mass.

MDCT identified the cause of hemoptysis in total 48 out of 52 patients (92%). Those 48 patients included 37 (71%) patients with lung parenchymal abnormalities and 11 (21%) patients with isolated vascular abnormalities without parenchymal abnormalities. Among those 37 patients with lung parenchymal abnormalities; 33 (63%) patients had associated vascular abnormalities (Figs. 1 and 2) and 4(8%) patients had no associated vascular abnormality. In the

Table 1 Demographic data, grades and etiology of hemoptysis in the studied patients.[*]

Parameter	Patients No (percent)
Age (years)	
Mean ± SD	50.15 ± 14.61
Range	20.0–75.0
Gender	
Male	37 (71%)
Female	15 (29%)
Grade of hemoptysis	
Mild	12 (23%)
Moderate	34 (65%)
Severe	6 (12%)
Etiology of hemoptysis	
Lung cancer	24 (46.1%)
Suspected	10
Known	14
TB sequelae	11 (21.1%)
Bronchiectasis	6 (11.5%)
Pneumonia	5 (9.6%)
Pulmonary embolism	4 (7.7%)
Pulmonary AVM	1 (2%)
Cryptogenic	1 (2%)

[*] TB, tuberculosis; AVM, arteriovenous malformation.

remaining 4 out of 52 patients of the study (8%), neither parenchymal nor vascular abnormalities were detected as the cause of hemoptysis. Table 2 shows details of these results.

MDCT angiography was able to detect the vascular source of bleeding in 44 out of 52 (85%) of the studied cohort. Bronchial arteries were the major source of bleeding, being detected in 31 (60%) patients. Table 3 shows these vascular abnormalities and their relation to parenchymal abnormalities.

A total of 92 bronchial arteries were detected in 34 out of 52 (65%) patients (30 right BAs; 2 patients had 2 double right-sided BA, and 62 left BAs; 56 patients had double left-sided BA) (Figs. 1 and 2) Twenty-nine out of 92 detected BAs (31%) were seen to be dilated (>2 mm) in 29 patients (16 right BAs and 13 left BAs) (Table 4). Forty-nine out of 92 (53%) detected bronchial arteries were traceable to the level of pulmonary hila.

With regards to the ostia of bronchial arteries, our results showed that 82/92 (89%) of the BAs seen were orthotopic, while 10/92 (11%) were ectopic (Table 4). The later were seen in 8 patients, 5 were right-sided (3 from the aortic arch, and 2 from the subclavian artery) and 5 were left-sided (2 from the aortic arch and 3 from lower part of descending thoracic aorta).

Notably, the origins of orthotopic mediastinal Bas were best depicted on overlapping axial thin-section images Two-dimensional MIP reformatted images in the coronal oblique and sagittal planes readily depict the tortuous course of the BAs from their origins (descending thoracic aorta) to the lungs along the main bronchi; whereas reformatted images in straight coronal planes were better suited for analysis of the intercostals and internal mammary arteries; and axial reconstructed images were ideal for demonstrating the inferior phrenic arteries and branches from the celiac axis (Figs. 1, 3 and 5).

Non-bronchial systemic source of bleeding was encountered in 6 (11.5%) patients (Table 3) in the form of: dilated

intercostals vessels with pleural thickening (>3 mm) and in association with parenchymal lung abnormalities in all of these patients.

The pulmonary circulation contributed to hemoptysis in 7 (13.5%) patients (Table 3 and Fig. 3), 4 of them had pulmonary embolism (Table 2 and Fig. 4) and 1 patient had arteriovenous malformation; AVM (Fig. 5).

DSA was performed after MDCT study in 9 (17%) patients who were indicated for embolization and showed positive findings in 8/9 (88.9%) patients, where abnormal BAs were identified in 7 patients and an abnormal NBSA was seen in one patient. (Figs. 1 and 2).

Upon comparing the findings with MDCT, all the BAs were prospectively identified as abnormal by MDCT.

Discussion

The current prospective study aimed to evaluate the role of MDCT in the management of hemoptysis of different etiologies and degrees among 52 patients, enrolled through a 3-year period, in Upper Egypt. To the best of our knowledge, this is the first study reporting the utility of MDCT, with bronchial and pulmonary angiography in the management of hemoptysis in Upper Egypt.

Identifying the etiology of hemoptysis and classifying it in terms of the amount of blood expectorated, as well as the rate of bleeding play a fundamental role in optimizing the management strategy and deciding whether or not an embolization procedure is needed. Our data showed that lung cancer was the most encountered cause for hemoptysis in our patients (46%), followed by those underlying chronic lung diseases with extensive vascular abnormalities, like TB sequelae and bronchiectasis, in 21% and 11.5% patients, respectively.

Despite the fact that the current study was carried out at the same locality (Upper Egypt) of the study by Agmy et al. [2], common etiologies of hemoptysis are clearly different between the 2 studies, which may be explained by the difference in patients' numbers. Moreover, lung cancer, being the most common etiology in the current study can be explained by enrollment of 11/52 (21%) patients with known lung cancer into the study. Our results are still in agreement with those of Hirshberg et al. [9] who found that lung cancer and bronchiectasis were the causes of hemoptysis in 20% and 19% of their patients, respectively.

Despite the fact that bronchial arteries are the most common source of massive or life-threatening hemoptysis due to the high pressure of that circuit, non-bronchial systemic circulation may contribute between 10% and 30% of cases [10] Missing the nonbronchial systemic arteries at initial angiography may result in early recurrent bleeding after successful embolization of the bronchial artery. So, a comprehensive search for non-bronchial systemic arterial supply should be made [2].

The normal BA is a small vessel that arises directly from the descending thoracic aorta and supplies blood to the airway of the lung, esophagus, and lymph nodes [11] Bronchial arteries show substantial anatomic variations in their origins, branching patterns, and courses [12]. The right intercostobronchial trunk, which usually arises from the right posterolateral aspect of the thoracic aorta at the level of the 5th thoracic vertebra or 6th thoracic vertebra, is the most constant vessel. In approxi-
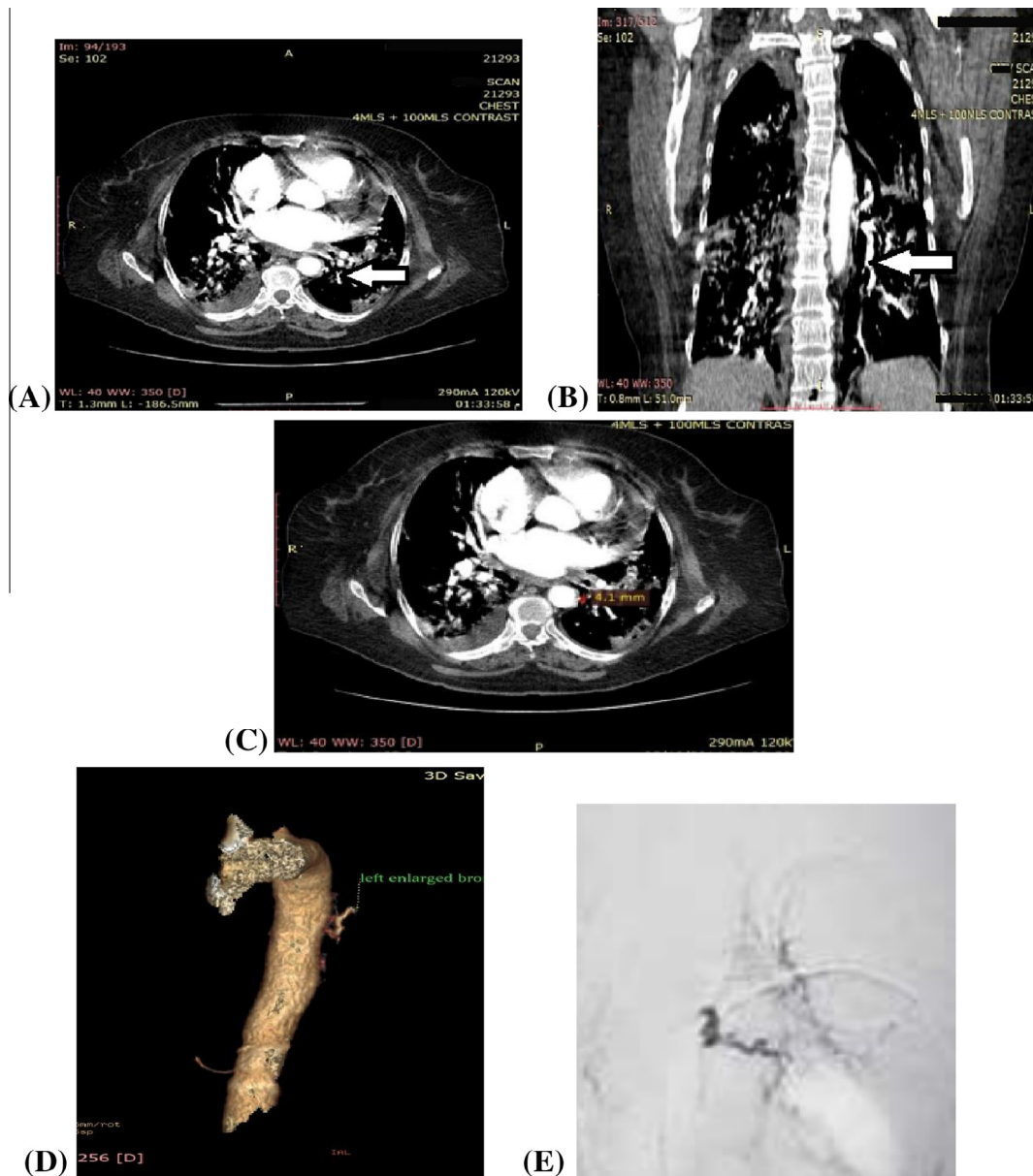
Figure 1 Male patient, 65 years old, presented with moderate haemoptysis for 2 weeks. MDCT of the chest; (A) Axial post contrast image (mediastinal window) shows bilateral consolidation with an air bronchogram with bilateral minimal pleural reaction. Note a dilated orthotopic left bronchial artery (white arrow). (B) Coronal image shows bilateral consolidation with a dilated left bronchial artery (white arrow), the diameter of which was 4.1 mm (axial view, C). A 3-D volumetric reformatted image (D) and conventional angiography also show this dilated artery.

mately 70% of cases, there are two left BAs. Right and left BAs that arise from the aorta as a common trunk are not unusual. BAs are identified in the posterior mediastinum as dots or lines of increased attenuation [13]. More than 30% of BAs have an anomalous origin, which is a cause of endovascular treatment failure [5]. Anomalous BAs may originate from the aortic arch, internal mammary artery, thyrocervical trunk, subclavian artery, costocervical trunk, brachiocephalic artery, peri-cardiophrenic artery, inferior phrenic artery, or abdominal aorta [5].

Imaging modalities used in the evaluation of hemoptysis include chest radiography, computed tomography, and bron-

chial arteriography. However, more recently, the development of multidetector row CT (MDCT) has provided a comprehensive, noninvasive method for evaluating the entire thorax [1,7]. At the same time, the combined use of thin-section axial scans and more complex reformatted images allows clear depiction of the origins and trajectories of abnormally dilated bronchial or non-bronchial systemic arteries that may be the source of hemorrhage requiring embolization [5,7].

In the current study, chest radiography contributed to the diagnosis of hemoptysis in 20/52 (38%) patients. This finding is nearly consistent with those obtained by Abdel-Ghany et al. [14] and Revel et al. [15], who reported that chest radio-
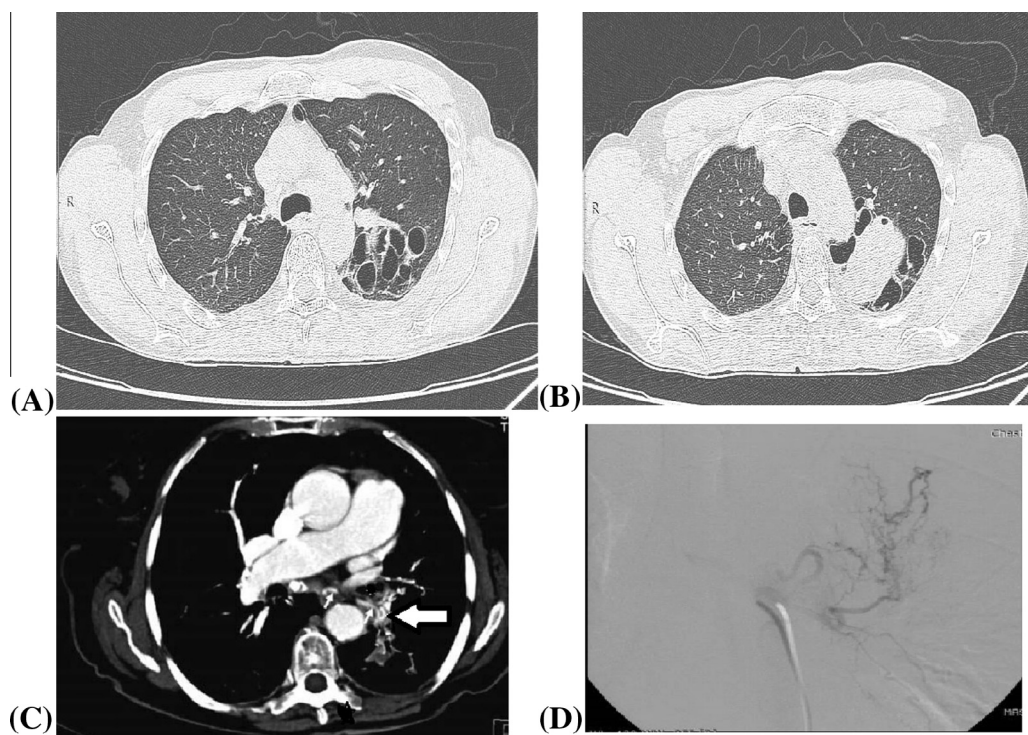
Figure 2 Male patient 55 years old, complaining of recurrent hemoptysis. MDCT of the chest; (A) Axial image (pulmonary window) showing bronchiectatic changes of the left lung with abnormal hyperdense patchy shadows inside the dilated bronchi (B). Axial MDCT (mediastinal window) at the carinal level shows dilated left bronchial artery (big arrow) with multiple nodular densities (small arrows). Conventional angiography (D) shows an enlarged tortuous left bronchial vessel at the same level.

Table 2 MDCT findings in the studied patients.[*]

Parenchymal abnormality	Patients No (percent)
Specific parenchymal abnormality	33 (63%)
Mass	2
TB sequelae	10
Bronchiectasis	6
Endobronchial mass with/without obstruction	15
Non-specific parenchymal abnormality (Consolidation/ground-glass opacity)	4 (8%)
Pneumonia	4
No parenchymal abnormality	11 (21%)
Bronchial artery vascular abnormality (dilatation/dysplasia)	6
Pulmonary artery vascular abnormality	5
Pulmonary embolism	4
Pulmonary AVM	1
Unidentified abnormality	4 (8%)

[*] TB, tuberculosis; AVM, arteriovenous malformation.

graphy contributed to diagnosis of hemoptysis in 44% and 46% of patients, respectively.

Our data revealed that, MDCT identified the cause of hemoptysis in 48 out of 52 patients (92%). These results are in agreement to those reported by Khalil et al., 90.5% [16] and even better than those reported by 2 Egyptian studies (86%, by Ismaeel et al. [8] and 84%, by Abdel-Ghany et al. [14].

With regards to the bleeding site localization, our data revealed that, the presence of bleeding was detected by abnormal CT findings in the form of focal parenchymal abnormality or opacity (either ground glass opacity or consolidation) that is not gravity-dependent. Diffuse opacities or those predominantly in the dependent portion of the lungs were considered non-localizing. Three types of non-specific radiologic MDCT abnormalities were prescribed in the literature [5,15,16]: (1) ground-glass opacities and/or (2) alveolar consolidation; the latter abnormalities were considered to reflect the filling of the alveolar lumen with blood, and (3) atelectasis, induced by clots obstructing the bronchi. The presence of alveolar filling, cavitation and/or a mass was considered to be localizing lesions.

Our data showed that MDCT angiography was able to detect the vascular source of bleeding in 44/52 (85%) of patients. Bronchial arteries were the major source of bleeding, being detected in 31 (60%) patients. A total of 92 BAs were detected in 34 out of 52 (65%) patients (30 right BAs and 62 left BAs). In the study by Abdel-Ghany et al. [14], MDCT chest with angiography detected 93 bronchial arteries in 32/50 (64%) patients. Using a 16-MDCT, Yoon, et al. [17], were able to detect 52 bronchial arteries in 22 patients.

Interestingly, 29 out of 92 detected BAs (31%) were seen to be dilated (>2 mm) in 29 patients (16 right BAs and 13 left BAs). Gupta and coworkers [5], with the use of a cutoff value of 2 mm on MDCT, could prospectively detect all abnormal bronchial arteries by MDCT before detecting them later with conventional angiography.

Table 3 Source of bleeding detected by MDCT and its relation to parenchymal abnormality.

Source of bleeding	No of patients (%)	With parenchymal abnormality No (%)	Without parenchymal abnormality No (%)
Bronchial artery Supply	31 (60%)	25	6
Non-bronchial systemic artery	6 (11.5%)	6	0
Pulmonary artery	7 (13.5%)	2	5
Not detected	8 (15%)	4	4

Table 4 Radiologic criteria of Bronchial arteries depicted on MDCT angiography.

Detected bronchial arteries		
	Orthotopic (82/92, 89%)	Ectopic (10/92, 11%)
Right (30)		
Dilated	16	2
Non-dilated	9	3
Left (62)		
Dilated	13	0
Non-dilated	44	5

MDCT has a great value in depicting the ostia of the bronchial arteries. We demonstrated that 82/92 (89%) of the BAs seen in our study were orthotopic, while 10/92 (11%) were ectopic. Those ectopic arteries were seen in 8 patients, 5 were right-sided (3 from the aortic arch, and 2 from the subclavian artery) and 5 were left-sided (2 from the aortic arch and 3 from lower part of descending thoracic aorta). These findings are in accordance with those reported in the literature. Abdel-Ghany and colleagues [14] found that that 90% of the BAs seen were orthotopic, and 10% were ectopic BAs (seen in 7 patients). Another study showed that the ostia of the BAs were orthotopic in 92.6% and ectopic in 7.4% of patients, respectively [5].

In our series, 49 out of 92 (53%) detected bronchial arteries were traceable to the level of pulmonary hila. Previous data [14] demonstrated that 46% of detected bronchial vessels (46%) were traceable to the pulmonary hilum, while Yoon et al. [17], found that 65% of BAs were traceable from their origins to the hilum. Helmy et al. [18] concluded that tortuosity and traceability of the vessels directed toward the lesion are important factors in identification of the source and site of bleeding.

One of the major causes of recurrent hemoptysis after successful embolization of bronchial arteries is the presence of

Figure 3 70 year old male patient presented with fever and mild hemoptysis for 2 weeks. MDCT chest; (A) Axial image (pulmonary window) shows a right middle lobe fibrocavitary lesion surrounded by a patchy area of consolidation. (B) Axial image (mediastinal window) showing consolidation with a branch from the Rt pulmonary artery is seen within the wall of the cavitary lesion. (C) Volume rendering 3-D processed imimage showing focal dilatation of the segmental pulmonary branch.
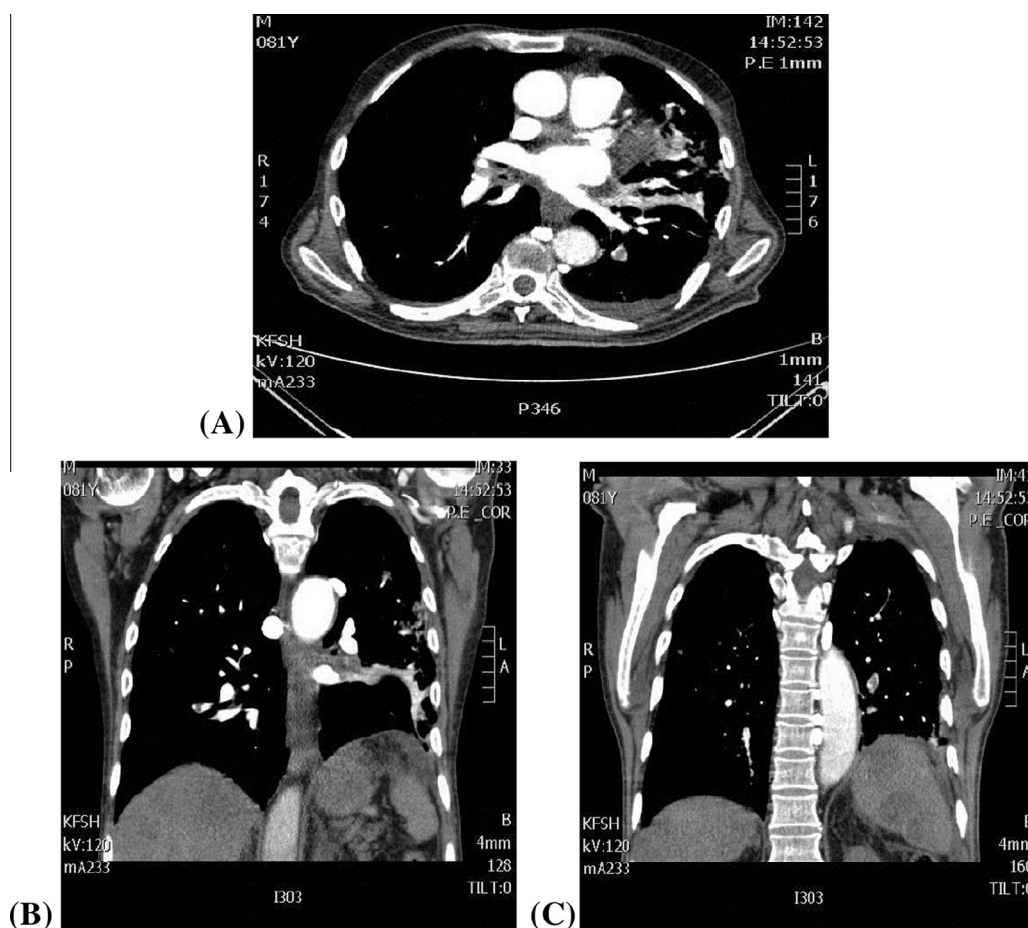
Figure 4 74 year old male patient presented with breathlessness, chest pains and hemoptysis of blood-tinged sputum for few days. MDCT chest with angiography; axial (A) and coronal images (B and C) show multiple arterial filling defects noted in the right and left descending pulmonary arteries as well as multiple arterial filling defects in the subsegmental branches, consistent with pulmonary embolism.

abnormal nonbronchial systemic arteries. We identified non bronchial systemic arteries in 6 (11.5%) of our patients. They were in the form of dilated intercostals vessels with pleural thickening and in association with parenchymal lung abnormalities in all of these 6 patients. Gupta and colleagues [5] had identified nonbronchial systemic arteries in 11 of 27 patients (40.7%). Three of these patients (11.1%) had normal bronchial arteries, and a nonbronchial systemic artery was the only source of hemoptysis. In a study by Goh et al. [10] of 103 patients who underwent BAE, 42 had nonbronchial systemic contributions (41%) and 12 had abnormal nonbronchial systemic arteries but normal bronchial arteries (11.7%). Wong et al. [19] found that nonbronchial collateral vessels supplied the bleeding area in 14 of 16 patients with life-threatening hemoptysis (88%). In 3 of those 16 patients (19%), bleeding from systemic vessels other than the bronchial arteries was the only source of hemoptysis.

Thus, our study also agrees with these studies and confirms the significant contribution of nonbronchial systemic arteries in patients with hemoptysis. Embolization of the nonbronchial systemic arterial supply can lower the immediate recurrence rate after successful embolization. Therefore, it is important to identify these abnormal nonbronchial systemic arteries before embolization.

Along with the evaluation of systemic arteries, MDCT also evaluates the pulmonary vasculature. Although in 95% of cases of hemoptysis, the systemic arterial system is the origin of the bleeding [12], pulmonary circulation can be the source of hemoptysis in approximately 5% of cases. Detecting pulmonary circulation as a source of hemoptysis before an interventional procedure changes the approach altogether. Various causes of hemoptysis due to pulmonary circulation include pulmonary emboli, Rasmussen aneurysm, direct invasion by neoplastic disease, and pulmonary arteriovenous malformation (AVM) [5].

Notably, the pulmonary circulation contributed to hemoptysis in 7 (13.5%) of our cohort, characteristically 4 of them had pulmonary embolism and 1 patient had AVM. In one patient, a branch from the Rt pulmonary artery was seen within the wall of a cavitary lesion in the right middle lobe (Fig 3). Previous studies had reported that the pulmonary circulation contributed to hemoptysis in 6.9% [20] and 10% [14] of patients, respectively.

Conventional bronchial angiography was performed after MDCT study in 9 (17%) patients who were indicated for embolization and showed positive findings in 8/9 (88.9%) patients, where abnormal BAs were identified in 7 patients and an abnormal NBSA was seen in one patient. Upon com-
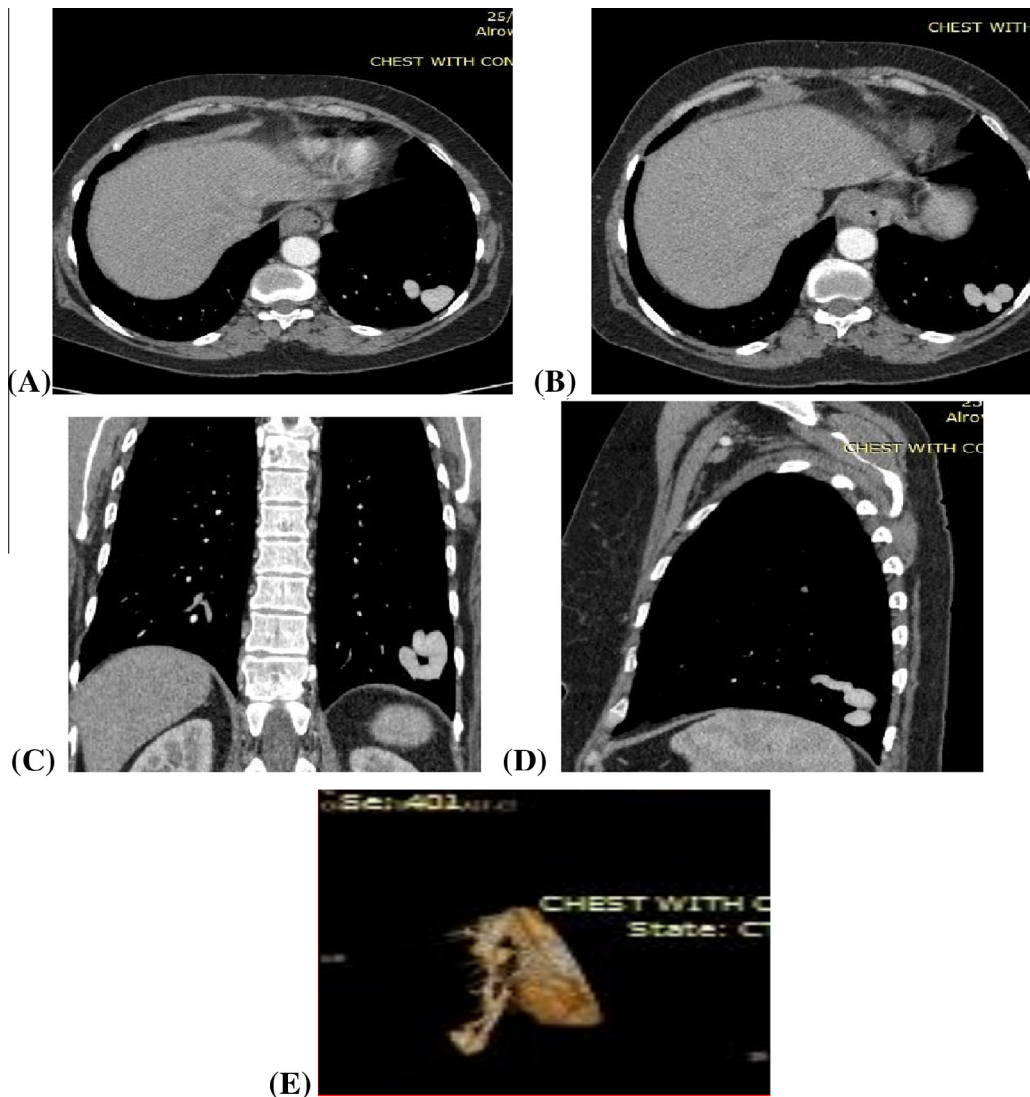
Figure 5 A female patient, 53 years old presented with mild hemoptysis of 3 weeks duration. MDCT chest with angiography; (A and B) post contrast axial views (mediastinal window) show a well defined lobulated lesion at the left lower lung lobe. Note the serpigenous vessels forming the lesion, which are also seen in the coronal (C) and sagittal (D) views. A 3-D volume rendering (E) shows a pulmonary arteriovenous malformation (AVM) with a connection between the left inferior pulmonary vein and lower branch of left pulmonary artery.

paring the findings with MDCT, all the BAs were prospectively identified as abnormal by MDCT.

To summarize, our 3-year experience confirmed those reported in the literature, that MDCT chest with angiography is considered a primary noninvasive imaging modality in the evaluation of patients with hemoptysis.

MDCT angiography is a useful method to identify and depict the bronchial arteries and to predict the presence of nonbronchial systemic vessels as well as pulmonary vasculature that supply a parenchymal lesion.

The current study has some limitations. First, we have used a 16-detector row MDCT device, Morita et al. [21] demonstrated that 64 slice CT scanners showed the bronchial artery anatomy better than 16 slice scanners. Second, is that the selective conventional angiography and bronchoscopy were performed in a limited number of patients.

To confirm our results, a larger or multi-center study is needed in which inter-observer variability, especially in defining BAs causing hemoptysis and those not causing hemoptysis, is recommended with use of MDCT and conventional angiography in all enrolled subjects.

Conclusion

Our 3-year experience confirms that MDCT chest with angiography is a useful method to identify and depict the bronchial arteries and to predict the presence of nonbronchial systemic vessels as well as pulmonary vasculature that supply a parenchymal lesion. By using a variety of reformatted images, MDCT angiography allows a rapid and detailed identification of abnormal vasculature and provides a precise road map

which can be used to guide further therapeutic arterial embolization procedures.

Competing interests

The authors declared no conflicts of interest.

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