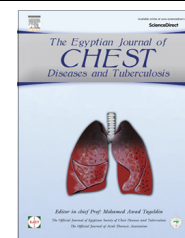




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ORIGINAL ARTICLE

Utility of multidetector row computed tomography and virtual bronchoscopy in evaluation of hemoptysis due to lung cancer



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KEYWORDS

Utility;
 Multidetector;
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Abstract *Background:* We aimed to evaluate the usefulness of multidetector row computed tomography (MDCT), with angiography, as well as its generated virtual bronchoscopy (VB) in the evaluation of patients with hemoptysis due to lung cancer.

Methods: A prospective study was carried out on 24 patients diagnosed as primary lung cancer and presented with hemoptysis, from May 2011 to August 2014. They underwent MDCT using a 16-detector row scanner with bronchial and pulmonary angiographic techniques. MDCT-generated VB was carried out and compared to findings obtained by fiberoptic bronchoscopy (FOB).

Results: MDCT identified the cause of hemoptysis and its angiography detected the site and vascular source of bleeding in 96% of patients. Virtual bronchoscopy had sensitivity, specificity, and accuracy of 91%, 50%, and 87.5%, respectively. While FOB detected 11, 19, 3 and 2 endoluminal lesions, obstructive lesions, external compressions, and mucosal abnormalities; VB detected 7, 25, 11, and 0 lesions, respectively.

Abbreviations BA, bronchial artery; BAE, bronchial artery embolization; CT, computed tomography; FOB, fiberoptic bronchoscopy; LC, lung cancer; MDCT, multidetector row computed tomography; MDCTA, multidetector row computed tomography angiography; MIP, maximum intensity projection; MPR, multiplanar reformation; SECI, South Egypt Cancer Institute; 3D, three-dimensional; TB, tuberculosis; 2D, two-dimensional; NBSAs, non-bronchial systemic arteries; VB, virtual bronchoscopy; VR, volume-rendered

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Conclusion: MDCT angiography is a useful and non invasive method that allows a rapid and detailed identification of abnormal vasculature responsible for hemoptysis in patients with lung cancer. MDCT-generated virtual bronchoscopy is an accurate, and non invasive method for evaluating obstructions, endoluminal masses, and external compressions in patients with hemoptysis due to lung cancer.

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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, and thoracic malignancy [3]. In the majority of cases, the source of massive hemoptysis is the bronchial circulation. However, nonbronchial systemic arteries can be also a significant source [2]. Regardless of the amount and etiology of hemoptysis, patients must be hospitalized immediately and must undergo urgent investigations including imaging and fiberoptic bronchoscopy, FOB [4].

Because patients with malignant tumors of the thorax frequently have complete bronchial obstructions caused by endoluminal tumors and extrinsic compression, a noninvasive, reproducible, and objective method for sequentially evaluating these abnormalities might prove useful in guiding therapy and assessing treatment response in these individuals [5]. Patients with hemoptysis due to suspected neoplastic lesion typically undergo conventional CT scanning of the chest, followed by FOB [4].

CT generates 2-D cross-sectional images of the thorax to provide information regarding peribronchial anatomy. In the evaluation of major endobronchial disease, CT scans have a sensitivity of 63–100% and a specificity of 61–99% [6]. Suboptimal scanning techniques, inappropriate slice thickness, and artifacts between sections may limit the accuracy of airway anatomy defined by conventional CT scans. FOB remains the best modality for evaluation of endoluminal and mucosal lesions; however, endoscopy yields no information about the extent of extraluminal disease or airway patency distal to a high-grade stenosis [7]. In addition, FOB poses a potential risk to the patient because of sedation; this risk may be increased in patients with advanced intrathoracic disease [8].

Recently, the development of multidetector row CT (MDCT) has provided a comprehensive, noninvasive method of evaluating the entire thorax [1,9]. MDCT angiography 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 [2].

Even more, physicians can now explore the tracheobronchial tree on volumetric three-dimensional images with the increasing sophistication in CT technology [10]. Virtual bronchoscopy is a promising computer-assisted imaging technique that allows a three dimensional (3D) evaluation of the tracheobronchial tree similar to those obtained during FOB. Although the technique was described in the mid 1990s, it is generating new interest as a result of improvements in

multidetector computed tomography and postprocessing technology [11]. It was found to be highly accurate in the detection of central airway stenosis and staging of lung cancer [12].

Assiut University Hospital and South Egypt Cancer Institute (SECI) are tertiary referral centers, where many patients, from all over Upper Egypt, are referred for the evaluation and management of hemoptysis and lung cancer.

Therefore, in the current study, we had 2 main aims; first is to report our experience with the use of MDCT and its angiographic technique in identifying the site of bleeding and its vascular origin in patients with hemoptysis due to lung cancer. Second, is to assess the diagnostic value of MDCT-generated virtual bronchoscopy in patients with hemoptysis due to lung cancer, in comparison to that of fiberoptic bronchoscopy, as the gold standard tool for diagnosing those patients.

Patients and methods

Patients

This prospective study was carried out on 24 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, with the diagnosis of suspected LC, and those admitted to the Department of Medical Oncology, South Egypt Cancer Institute (SECI), with newly-diagnosed primary LC. The later received neither chemotherapy nor radiotherapy. All patients were subjected to complete clinical assessment. A detailed history was obtained. Final diagnosis in patients with suspected LC was established applying all clinical, laboratory, radiographic, MDCT, bronchoscopic, and histopathologic findings.

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) [13].

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 they become stabilized.

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

All enrolled patients were subjected to (1) plain chest X-ray (2) MDCT with angiography for assessment of the integrity of pulmonary and/or systemic circulation. (3) MDCT-integrated

virtual bronchoscopy (4) fiberoptic bronchoscopy (FOB) with histopathologic examination. Virtual bronchoscopy was done 24 h before FOB. The pulmonologist carried out FOB blindly and independently from the results of VB. Findings obtained by FOB were considered the “gold standard” for comparison with those obtained by VB [14].

The study was approved by the local ethics committee 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 and post contrast CT studies were performed to 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 milliamperes-seconds (90–140) according to the patients weight the radiation dose to the patient can be minimized without affecting the image quality.

The MDCT bronchial angiographic technique

CT imaging was 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, multiplanar 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 reconstruction (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 ≥ 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 (≥ 3 mm) and/or lung parenchyma abnormalities. Whenever an abnormal nonbronchial systemic artery was identified, its origin and course were noted.

Virtual bronchoscopy

During the VB examination, the tracheobronchial tree was screened axially with 0.6 mm slices from the thoracic inlet to the end of the diaphragm after administering intravenous contrast material. Axial CT, coronal and sagittal MPR images with a slice thickness of 1 mm and with section intervals of 1 mm were reconstructed. Two-dimensional views were evaluated at the standard parenchymal window (level –600, width 1200) and mediastinal window (level –40, width 400) for lesions' endobronchial extensions, relations with neighboring structures and accompanying pathologies.

The tracheobronchial tree was investigated with an objective comparison between VB and FOB. Endoluminal, obstructive, and mucosal pathologies were defined and grouped according to Finkelstein and coworkers' classification [11] as follows; endoluminal mass is defined as a mass protruding into the lumen with $< 50\%$ occlusion, obstructive lesion is defined as bronchial narrowing of $> 50\%$, and mucosal lesion is defined by the presence of hemorrhage, erythema, or tissue

friability. Moreover, external compressions detected via VB and MPR findings were recorded.

Fiberoptic bronchoscopy

Fiberoptic bronchoscopy was performed by a pulmonologist, within 24 h after VB. Bronchoscopies were performed via the oral or nasal route with a flexible fiberoptic bronchoscope (Pentax SB 15; Pentax, Japan) under local anesthesia (Lidocaine HCl 10 mg/dose spray – midazolam 5 mg IV). Lesions of the tracheobronchial tree were grouped as ‘endoluminal lesions’ and ‘obstructive lesions’ as with VB. The presence of mucosal lesions and external compression was also recorded. During FOB, samples were obtained using biopsy forceps, needle aspiration (A 13-mm 21-gauge cytology needle; NA-2C-1; Olympus Corporation), brushing, bronchoalveolar lavage or a few of them accordingly. A specialized pathologist evaluated the materials. Final diagnoses were approved by histopathological analysis of specimens obtained during bronchoscopy.

Statistical analysis

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

FOB results were used as a reference for comparison with VB results [11,14]. Qualitative results regarding the description of tracheobronchial abnormalities with VB were defined as true-positive, true-negative, false-positive and false negative findings. A true-positive finding was classified as an abnormality noted in both image modalities (FOB and VB), whereas a true-negative finding was defined as an absence of airway abnormalities on FOB and VB. A false-positive finding was defined as a tracheobronchial section noted as abnormal on VB but normal on FOB. A false-negative finding was defined as a tracheobronchial section that appeared normal on VB but abnormal on FOB. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy were calculated as follows: sensitivity: true-positive/false-negative + true-positive; specificity: true negative/false-positive + true-negative; PPV: true-positive/true-positive + false-positive; NPV: true-negative/true negative + false-negative; accuracy (%) = $100 \times (\text{true-positive} + \text{true-negative}/\text{true-positive} + \text{false-positive} + \text{true-negative} + \text{false-negative})$.

Results

Twenty-four patients were prospectively enrolled into the current study. They included 20 (83.3%) males and 4 (16.7%) females with a mean age of 54 years (range from 33 to 78). Nineteen out of 24 patients (79%) were cigarette smokers, with a mean total pack/year of 78.1. Histopathologic diagnosis revealed that 22 out of 24 patients (91.7%) had non-small cell lung cancer (NSCLC), while 2/24 (8.3%) had small-cell lung cancer (SCLC). Twenty-two out of 24 (92%) tumors were centrally located, while 2/24 (8%) were peripherally located. Table 1 shows these results. Plain chest X ray was considered as successfully contributing in identification of the cause of hemoptysis in 17/24 (70%) patients.

MDCT identified the cause of hemoptysis in 23 out of 24 patients (96%). Those 23 patients included 20 (83.3%) patients

Table 1 Demographic data and histopathologic diagnosis of the studied patients.

Parameter	Patients No (percent)
Age (years)	
Mean \pm SD	54.20 \pm 12.82
Range	33.0–78.0
Gender	
Male	20 (83.3%)
Female	4 (16.7%)
Smoking history	
Non-smokers	5 (21%)
Smokers	19 (79%)
Total pack/year (Mean \pm SD)	78.1 \pm 44.2
Grade of hemoptysis	
Mild	7 (29%)
Moderate	17 (71%)
Lung cancer at presentation	
Suspected	10 (42%)
Known	14 (58%)
Location of lung cancer	
Central	22 (92%)
Peripheral	2 (8%)
Histopathologic diagnosis	
Squamous cell carcinoma	16 (67%)
Adenocarcinoma	3 (13%)
Large cell carcinoma	2 (8%)
Small cell carcinoma	2 (8%)
Undifferentiated carcinoma	1 (4%)

with lung parenchymal abnormalities and 3 (16.7%) patients with isolated vascular abnormalities without parenchymal abnormalities. All patients with lung parenchymal abnormalities had associated vascular abnormalities (Fig. 1). In the remaining 1 out of 24 patients of the study (4%), 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 23/24 (96%) of the studied cohort. Bronchial arteries were the major source of bleeding, being detected in 18 (75%) patients. Table 2 shows these vascular abnormalities and their relation to parenchymal abnormalities. A total of 38 bronchial arteries was detected in 18 out of 24 (75%) patients (13 right BAs, and 25 left BAs; 2 patients had double left-sided BA) (Fig. 1). Twelve out of 38 detected BAs (31%) were seen to be dilated (>2 mm) in 10 patients (5 right BAs and 7 left BAs) (Table 3). Twenty-four out of 38 (63%) detected bronchial arteries were traceable to the level of pulmonary hila.

With regard to the ostia of bronchial arteries, our results showed that 35/38 (92%) of the BAs seen were orthotopic, while 3/38 (8%) were ectopic (Table 3). The latter was seen in 3 patients, 1 was right-sided (from the aortic arch) and 2 were left-sided (from the 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

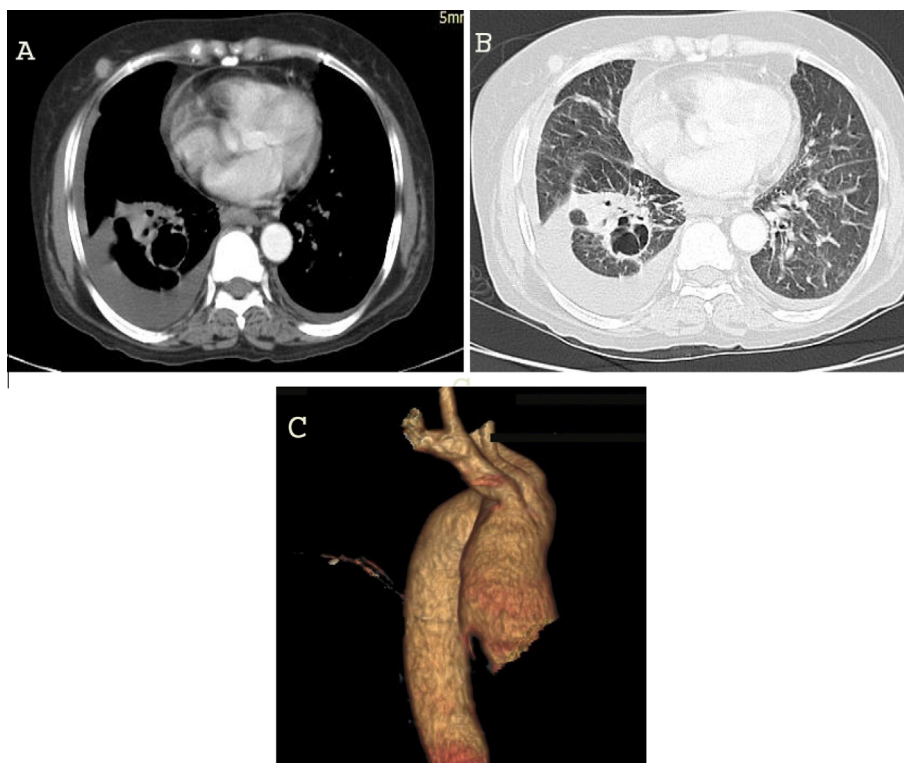


Figure 1 Female patient 65 years old, complaining of mild hemoptysis of 1 month duration. MDCT of the chest shows an irregular thickened wall cavitary lesion in both mediastinal (A) and pulmonary (B) windows, in the posterior segment of the right lower lobe. Right sided pleural effusion and subcutaneous nodule are also identified. Bronchoscopic biopsy revealed squamous cell carcinoma. A 3-D volume rendering (C) showed enlarged right bronchial artery originating from the aorta and supplying the cavitary lesion.

Table 2 Source of bleeding detected by MDCT and its relation to parenchymal abnormalities.

Source of bleeding	No of patients (%)	With parenchymal abnormality No (%)	Without parenchymal abnormality No (%)
Bronchial artery	18 (75%)	16	2
Non-bronchial systemic artery	2 (8%)	2	0
Pulmonary artery	3 (13%)	2	1
Not detected	1 (4%)	0	1

Table 3 Radiologic criteria of bronchial arteries depicted on MDCT angiography.

Detected bronchial arteries	Detected bronchial arteries	
	Orthotopic (35/38, 92%)	Ectopic (3/38, 8%)
Right (13)		
Dilated	4	1
Non-dilated	8	0
Left (25)		
Dilated	7	0
Non-dilated	16	2

along the main bronchi; whereas reformatted images in straight coronal planes were better suited for the 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.

Non-bronchial systemic source of bleeding was encountered in 2/24 (8%) patients (Table 2) in the form of dilated intercostal vessels with pleural thickening (> 3 mm) and in association with parenchymal lung abnormalities in these 2 patients.

The pulmonary circulation contributed to hemoptysis in 3/24(13%) patients (Table 2).

With regard to the results obtained by VB and FOB, our data showed that, in 22 out of the 24 patients (92%), tracheo-bronchial abnormalities were present on FOB, whereas 2 patients (8%) had normal findings on FOB. None of the patients had “pure” tracheal abnormalities. In 20 of these 22 patients (91%), VB confirmed the abnormality diagnosed by FOB. Two patients (9%) with abnormalities on FOB had normal findings on VB. One patient had normal findings on both VB and FOB. One patient with normal findings on FOB had an abnormality according to VB (Fig. 2). Based on these numbers, sensitivity and specificity were calculated for VB as 91% and 50%, respectively, whereas PPV and NPV were 95% and 33%, respectively. Accuracy was 87.5%.

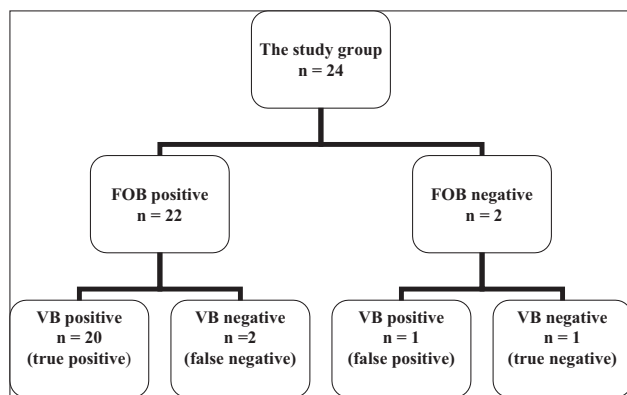


Figure 2 Diagnostic yields of virtual bronchoscopy (VB) and fiberoptic bronchoscopy (FOB).

According to the final diagnosis based on histopathological findings, FOB had a sensitivity of 100% and specificity of 50%, PPV of 95.6% and NPV of 100%.

With regard to the numbers and types of lesions detected by VB and FOB, our results showed that; while FOB detected 11 endoluminal lesions, VB detected 7. While FOB detected 19 obstructive lesions, VB detected 25. (Table 4, Figs. 3 and 4).

In evaluating external compression, FOB detected 3 lesions and VB detected 11. For the mucosal pathologies, while VB did not provide any information, FOB detected 2 mucosal pathologies. (Table 4).

Discussion

The current prospective study aimed to evaluate the role of MDCT with bronchial and pulmonary angiography, as well as virtual bronchoscopy, in the evaluation of hemoptysis due to lung cancer among 24 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 angiography, and VB in evaluating hemoptysis due to lung cancer, in Upper Egypt.

Primary lung cancers account for 23% of cases of hemoptysis in the United States. Bronchogenic carcinoma is a common lung cancer responsible for hemoptysis in 5–44 percent of all cases [15]. In concordance with these reports, in our results, all patients had the diagnosis of bronchogenic carcinoma, and as 92% of the these tumors were centrally located, hemoptysis is an anticipated presentation in our cohort.

Bleeding from malignant or benign tumors can be secondary to superficial mucosal invasion, erosion into blood vessels, or highly vascular lesions. Breast, renal, and colon cancers

have a predilection for lung metastasis; however, metastatic lung carcinoma rarely results in bleeding [11]. Obstructive lesions may cause a secondary infection, resulting in hemoptysis.

Imaging modalities used in the evaluation of hemoptysis include chest radiography, computed tomography, and bronchial arteriography. More recently, the development of multi-detector row CT (MDCT) has provided a comprehensive, noninvasive method of evaluating the entire thorax [9]. One more advantage of MDCT is the use of MDCT angiography (MDCTA), which provides a detailed depiction of bronchial and non bronchial systemic arteries, which is very important in planning further management, including embolization procedures [16].

Our data revealed that, MDCT identified the cause of hemoptysis in 23 out of 24 patients (96%). These results are in agreement to those reported by Khalil et al., 90.5% [17]. Moreover, our data showed that MDCT angiography was able to detect the vascular source of bleeding in 23/24 (96%) of patients. Bronchial arteries were the major source of bleeding, being detected in 18/24 (75%) patients. A total of 38 bronchial arteries were detected in 18 out of 24 (75%) patients. Thirty-one percent of the detected BAs were seen to be dilated.

Our findings are in agreement with those of previous reports that showed that the source of bleeding, particularly in severe hemoptysis, originates from the bronchial and pulmonary arteries in 90% and 5% of cases, respectively [2,10]. In the remaining 5% of cases, hemoptysis may derive from non bronchial systemic arteries. In addition, MDCTA revealed that the non-bronchial systemic and pulmonary circulations contributed to hemoptysis in 8% and 13% of patients, respectively.

One of the major causes of recurrent hemoptysis after successful embolization of bronchial arteries is the presence of abnormal nonbronchial systemic arteries. So, it is important to identify these abnormal nonbronchial systemic arteries before embolization.

To report our experience with the use of VB and its utility in hemoptysis due to LC, VB was carried out and its results were compared to those of the FOB.

Virtual bronchoscopy (VB), also referred to as computerized tomographic bronchography, is a technique that makes use of 3-dimensional (3-D) reconstruction of high-resolution helical CT images for noninvasive evaluation of the tracheobronchial tree [10]. The basics behind using these high-resolution CT techniques, is that VB exploits the natural contrast between the air in the tracheobronchial tree and the soft tissue of the airway wall to establish a plane for generating the virtual airway; so the images are used to generate a 3-D model of airway anatomy. Once the virtual airway is created, the viewer can navigate through the airway in a 3-D manner analogous to standard FB [10,11]. In addition, VB allows for unconventional images, such as retrograde views of endoluminal and extraluminal anatomy. The airway can be manipulated in space and evaluated from multiple angles.

Evaluation of patients with hemoptysis due to suspected lung cancer include the use of plain radiology, conventional CT (better to use the MDCT if available), and FOB. In addition, MDCT can be used with angiography (MDCTA) and to generate VB.

In most studies evaluation of the airways, FOB was used as the reference 'gold standard' for comparison between FOB and

Table 4 Number of lesions detected by virtual bronchoscopy and fiberoptic bronchoscopy*.

	FOB	VB
Endoluminal lesion	11	7
Obstructive lesion	19	25
External compression	3	11
Mucosal findings	2	0

* FOB; fiberoptic bronchoscopy, VB; virtual bronchoscopy.

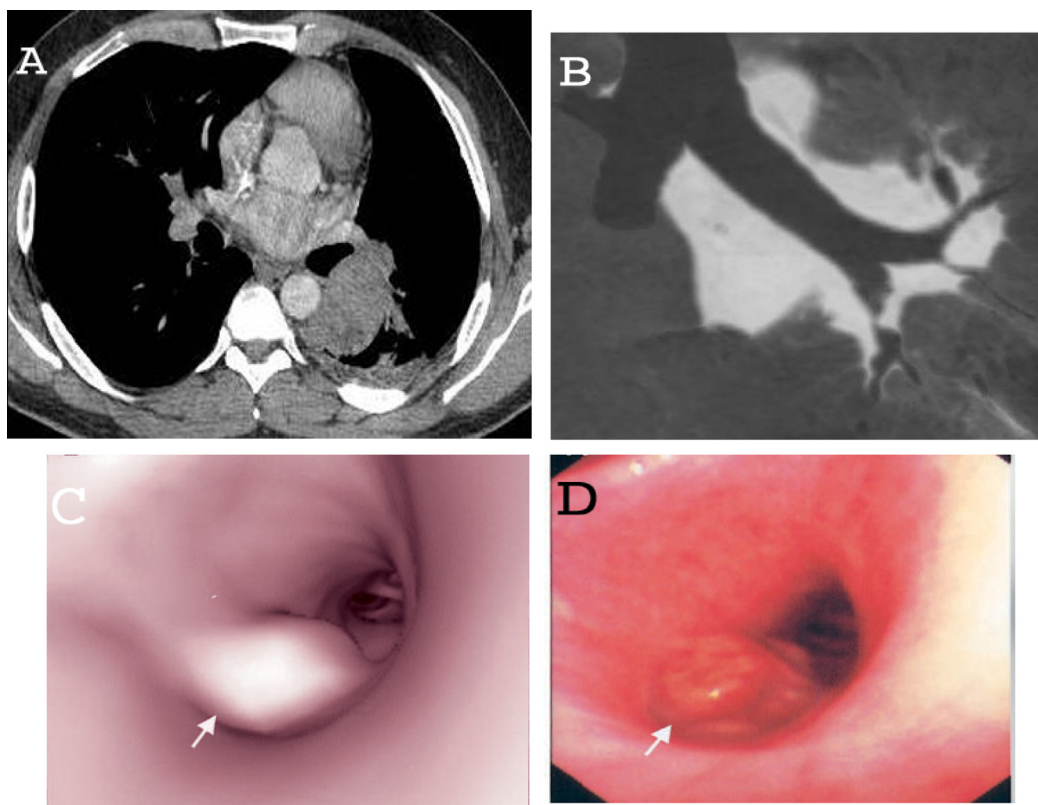


Figure 3 A male patient, 52 years old, presented with moderate haemoptysis for 2 weeks. MDCT of the chest; axial CT image (A) shows a large well defined irregular left hilar mass abutting the descending thoracic aorta. A distal consolidation patch is noted. Coronal reformatting using minimum intensity projection (B) showing subtotal occlusion of the left lower lobe bronchus with patent distal bronchioles. An endoluminal lesion (white arrows) obstructing the superior segment of the left lower lobe is seen at both virtual bronchoscopy (C) and fiberoptic bronchoscopy (D). Bronchoscopic biopsy revealed squamous cell carcinoma.

VB [12,14]. In our study, we utilized the yield by FOB as a 'gold standard reference' for comparing the results of VB. Therefore, the pulmonologist who performed the FOB was blinded to the results of the VB.

Our results revealed that VB had sensitivity, specificity, and accuracy of 91%, 50%, and 87.5%, respectively. These findings are in agreement to those reported in the literature [10,11,14,18].

Finkelstein and coworkers [11] examined 32 patients with thoracic malignant tumors via VB and compared the results with those of FOB. They observed that 13/20 (65%) patients had a total of 22 abnormal findings on FOB. VB detected 18/22 abnormal FOB as follows; 13 of 13 obstructive lesions, 5 of 6 endoluminal lesions, and 0 of 3 mucosal lesions. The sensitivity of VB was 100% for obstructive lesions, 83% for endoluminal lesions, 0% for mucosal lesions, and 82% for all abnormalities; and the specificity of virtual bronchoscopy was 100% [11].

In an Egyptian experience, Sharaf El Din et al. [12] assessed the roles of VB and FOB in staging LC. Twenty patients with primary LC were evaluated. Seventeen cases with central tumors were detected by both FOB and VB. They observed that, broadening of the main carina was reported in 5 cases by FOB and in 2 cases by VB, narrowing of lobar and segmental bronchi was reported in 7 cases by both VB and FOB. Whereas FOB reported vocal cord lesions in 4 cases, tracheo-bronchial mucous membrane lesions in 9 cases, broadening of

interlobar and intersegmental carina in 4 cases; VB supplemented by HRCT detected peripheral tumors, lymphadenopathy, lung parenchyma lesions, pleural effusion, and bony deposits [12].

With regard to the numbers and types of lesions detected by VB and FOB, our results showed that; while FOB detected 11 endoluminal lesions, VB detected 7. While FOB detected 19 obstructive lesions, VB detected 25. In evaluating external compression, FOB detected 3 lesions and VB detected 11. For the mucosal pathologies, while VB did not provide any information, FOB detected 2 mucosal pathologies (Table 4).

Virtual bronchoscopy detected endoluminal lesions as effectively as FOB, except for 4 locations in 2 patients. In the retrospective assessment of these 2 patients detected by FOB but not by VB, the result of VB did not change and the difference was thought to be due to the size of the lesions.

Our data showed that VB detected obstructive lesions as effectively as FOB. This agrees with previous data [11,14] VB can be performed in regions distal to stenoses, where FOB was not possible. Because of this advantage, it is thought that VB might be used to complement FOB in selected cases. In the literature, VB was found to be superior to FOB in the evaluation of regions beyond stenoses and in grading stenoses [19].

FOB cannot show the situation in regions distal to severe stenoses or total occlusion, the extension of the tumor, or whether a collapse has occurred or not. Virtual bronchoscopy, on the other hand, may be used to assess the bronchus distal to

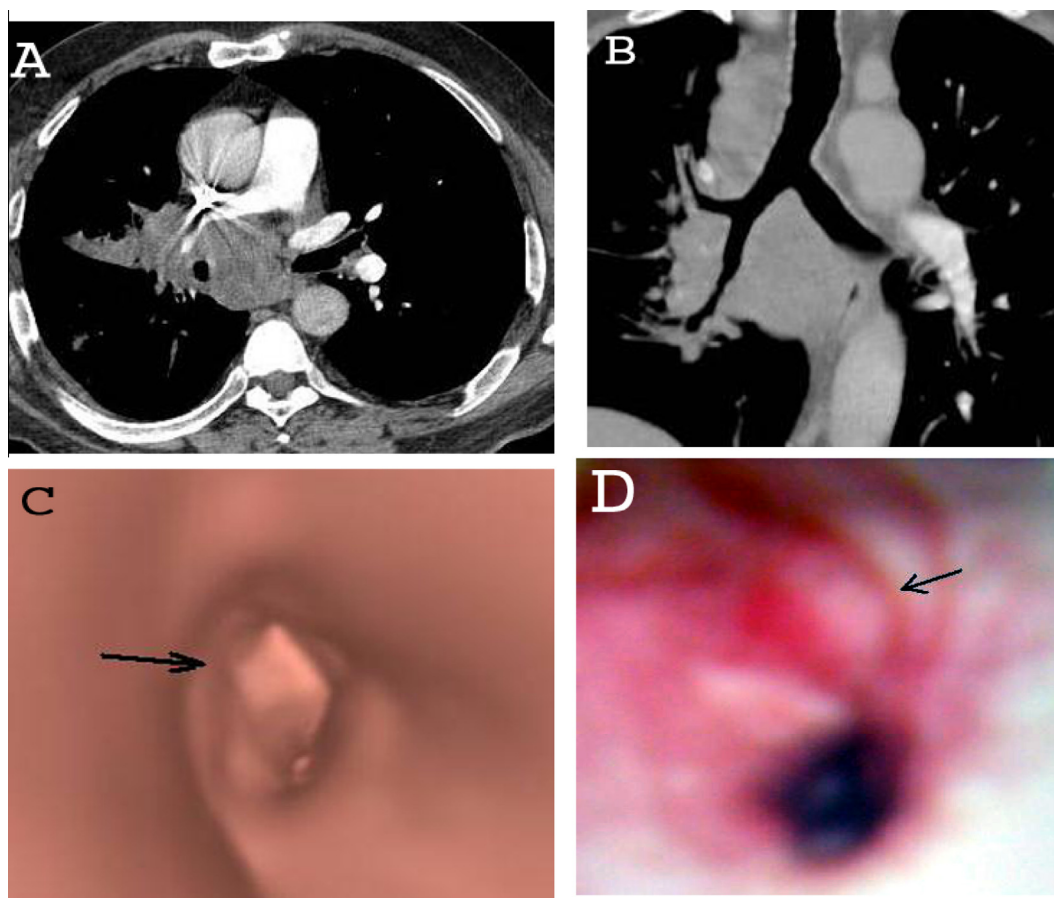


Figure 4 A male patient, 53 years old, presented with attacks of haemoptysis. MDCT of the chest; axial CT image (A) shows multiple pretracheal and subcarinal lymphadenopathy. A large right sided ill defined mass encasing and attenuating the inferior branch of the right main pulmonary artery as well as the bronchus intermedius is seen. Coronal reformatting (B) showing attenuated distal right bronchus intermedius and lower lobe bronchus with complete obstruction of the middle bronchus. Virtual bronchoscopy image (C); complete occlusion of the middle lobe bronchus and attenuated bronchioles of the lower lobe bronchus. FOB image (D) shows a mass completely obstructing the middle lobe bronchus associated with circumferential narrowing of subsegments of the lower lobe bronchus. Bronchoscopy guided biopsy revealed undifferentiated carcinoma.

the stenoses, the length of the stenoses and their positional location [18,19]. These details are important for endobronchial procedures such as laser therapy, stent placement and trans-bronchial radiotherapy [10,11].

While FOB is difficult to use in evaluating external compressions, VB with the help of MPR may provide comprehensive information. In the current study, while FOB detected 3 external compressions, VB detected 11. Adali et al. [14], in their study of 22 patients, reported that FOB detected 2 external compressions, while VB detected 15.

Via multiplanar images, VB allows quantitative measurements like the size of a lesion, its relationship with neighboring structures, the length of a stenosis and the diameter of a bronchus. Therefore, in the evaluation of patients for surgery, in contrast to FOB, VB and MPR should be considered together [10].

For mucosal pathologies, our data showed that only 2 lesions could be detected by FOB while VB could not detect any mucosal abnormalities. The low number of these mucosal lesions in the present study can be explained by the fact that 14/24 (58%) of our cohort had known LC. Our data, again,

are in agreement with those studies that reported a 0% sensitivity of VB in detecting mucosal pathologies [11,14].

Every procedure has advantages and disadvantages. FOB allows the direct evaluation of endoluminal and mucosal lesions and can guide biopsies for histological analysis. It also provides better assessment of mild degrees of stenosis. However, FOB has some limitations. It cannot pass through severely narrowed airways. It provides scarce information concerning the extent of extraluminal disease and it cannot be tolerated by some patients [10,20]. Virtual bronchoscopy is particularly useful for orientation within the tracheobronchial tree, and permits differentiation between intraluminal lesion and extraluminal airway compression. Virtual bronchoscopy allows one to assess the distal lesions and see beyond a stenosis. It may be able to distinguish between high-grade stenosis and complete occlusion [11,18,19].

Virtual bronchoscopy has some disadvantages, namely it cannot be used to evaluate mucosal details (eg. fragility, color changes, vascularity), to show mucosal or submucosal extensions, or to perform a biopsy, and also this method cannot be used to depict functional stenoses due to

tracheobronchomalasia [21]. The other limitation of VB was that it cannot be used to obtain a histological diagnosis (mucus plug, foreign body, embolism, benign mass and carcinoma) [18]. Despite these disadvantages, improved resolution and a probable increase in diagnostic abilities are expected to occur due to technological developments [10].

It is thought that we should look to FOB and VB as complementary, rather than competing methods, for evaluating patients with tracheobronchial abnormalities, particularly those with suspected LC [12,14], and we think that VB will never completely replace FOB for the evaluation of such patients. While FOB provides visualization and pathological specimens, VB provides only visualization with a wider scope than FOB.

The current study has some limitations. First, we have used a 16-detector row MDCT device, Morita et al. [22] demonstrated that 64 slice CT scanners showed the bronchial artery anatomy better than 16 slice scanners. Second, is the relative low number of enrolled patients. To confirm our results, a larger or multi-center study is warranted.

Conclusion

Our data confirm that MDCT angiography is a useful and non invasive method that allows a rapid and detailed identification of abnormal vasculature responsible for hemoptysis in patients with lung cancer. Moreover, MDCT-generated virtual bronchoscopy is an accurate, valuable and non invasive method for evaluating obstructions, endoluminal masses, and external compressions in patients with hemoptysis due to lung cancer. Virtual bronchoscopy and FOB are complementary tools for evaluating those patients.

Competing interests

The authors declared no conflicts of interest.

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