Role of multi-detector Computed Tomographic (CT) angiography, in patients with hemoptysis.

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Aims and objectives

Hemoptysis is defined as the spitting or coughing up of blood, caused by bleeding of the lungs or from the tracheobronchial tree. It may be a symptom of several diseases, more or less severe, but its appearance induces concern to the patient and requires a full diagnostic investigation.

The majority of patients will have an identifiable source and cause for the bleeding at the time of initial diagnosis [1].

The etiology for hemoptysis varies among different series according to time of publication, the geographic location, and the diagnostic tests employed. **Table 1.** Conditions such as lung malignancy, acute infections, tuberculosis, chronic bronchitis, chronic fungal infection and bronchiectasis, are some of the most common underlying causes of hemoptysis and are easily detected with C#.

Cryptogenic hemoptysis, for which no cause can be identified, is responsible for 3.0%-42.2% of episodes of hemoptysis, particularly in smokers. It is actually a diagnosis of exclusion [2], and warrants subsequent follow-up imaging to exclude possible underlying malignancy.

The bronchial circulation is the most frequent source of hemoptysis, but various nonbronchial systemic arteries and pulmonary arteries (vascular anomalies such as pulmonary arteriovenous malformations), may also contribute, depending on the underlying disorder. Rupture is usually caused by elevated regional blood pressures or vessel wall erosion by bacterial pathogens.

**Table 1. Etiology of hemoptysis**

| Infection: chronic inflammatory lung disease (i.e, acute/chronic bronchitis), bronchiectasis (including cystic fibrosis), lung abscess, aspergilloma, tuberculosis. |
| Neoplasm: bronchogenic carcinoma, pulmonary metastases, bronchial adenoma, sarcoma |
| Foreign body/Trauma: Broncholith, aspirated foreign body, trancheovascular fistula, chest trauma |
| Cardiac/pulmonary vascular: left ventricular failure, mitral valve stenosis, pulmonary embolism, infarction, pulmonary artery perforation (complication of pulmonary artery catheter) |
| Alveolar hemorrhage: Good pasture’s syndrome, systemic vasculitis, collagen vascular disease, drugs, coagulopathy. |
### Iatrogenic causes:
- Post lung biopsy, ruptured pulmonary artery from Swan-Ganz catheter

### Other:
- Pulmonary AVM, bronchial telangiectasia, pneumonoconiosis.

Critical technologic advances in CT, particularly the development of multi-detector row CT, have introduced a comprehensive, noninvasive method of evaluating the entire thorax, allowing detailed assessment of the mediastinum and lung parenchyma, focusing on locating the bleeding site and determining the cause of hemoptysis. MDCT angiography permits noninvasive, rapid, and accurate assessment of the cause and consequences of hemorrhage into the airways and helps guide subsequent management. More importantly, contrast-enhanced MDCT can demonstrate the site of bleeding as accurately as bronchoscopy (according to recent literature and clinical studies) and detect underlying disease with high sensitivity.
Methods and materials

From January 2010 to December 2011 a retrospective study was performed on consecutive patients admitted for hemoptysis, to the University Hospital of Athens. Fifty one patients were included and no other limitation factor was considered. Medical records with a hospital diagnosis of hemoptysis were reviewed for the following information: age, sex, medical history, the amount of bleeding as determined by the admitting physician, use of diagnostic tests and definitive diagnosis.

MDCT Protocol

MDCT evaluation of systemic vascularization (bronchial and nonbronchial) was performed using a 64 and a 16-MDCT scanner. The imaging parameters were commonly as follows: collimation 64x0.625, pitch 1.014, rotation time 0.75sec, reconstruction l dose 4, thickness 1mm, kv100, threshold 150, post threshold delay 8sec, increment 0.5 and mAS/slice 200mA.

Eighty milliliters (25.6 g I) of nonionic contrast agent (iodixanol 652 Visipaque 320) was administered IV at a rate of 3.5 mL/s via an automated injector device through an 18-gauge IV catheter. A region of interest was placed on the descending aorta. When the density reached 120 H, craniocaudal scanning started 6 seconds later from the lung apex to the lung base; imaging was performed with the patient in the supine position at maximal inspiration during a single breath-hold. Real-time axial scrolling, interactive maximum intensity projection, and volume-rendered techniques, were also used, to evaluate the origin and course of the bronchial and nonbronchial arteries.
Results

Fifty one patients were studied, 38 males and 13 females with an average age of 48 years old. CT scans were available for all 51 patients. In fifteen of those (30.4%), MDCT revealed acute and chronic infection findings considered to be associated with the bleeding, such as: localized ground glass infiltrates alone or accompanied by hazy consolidations and nodules, alveolar opacities, atelectasis, tree in bud opacities and bronchiectasis. Among them one patient was diagnosed with TB, one with NHL and invasive aspergillosis and another with AML and infection (images 1,2,3,4,5,6).

Lung malignancy was another leading cause of hemoptysis with a percentage of 20% (images 7,8,9). Among these patients, 8 had primary bronchogenic carcinoma and 2 had metastatic carcinoma to the lungs. Involvement of the thoracic vasculature as a bleeding mechanism, was present in 17.8% of the cases, with the involvement of varicose pneumonic veins in one patient, dilatation of the bronchial arteries, due to different causes in 6 patients, pulmonary sequestration and vascular dysplasia in two patients (images 10,11,12). Congestive heart failure, pulmonary edema and pulmonary embolism were also conditions in our cohort that were manifested with hemoptysis (images 13,14,15).

We have also identified a patient with hemoptysis after being exposed to amiantus with opacities, nodules and pleural thickening and another two (smokers) with no apparent cause (3.9%) (image 16,17).
Images for this section:

**Fig. 1:** MDCT- coronal and sagittal, MIP reconstruction images, in a patient with pneumonic infection and hemoptysis. Bilateral, multiple, diffuse, centrilobular nodules, that congregate especially in the right upper lobe, and a tree in bud configuration, in the subpleural spaces, are depicted. There is also significant peribronchial thickening.

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Fig. 2: MDCT-Coronal and sagittal MIP reconstruction images in lung window shows: Presence of a thick wall cavity at the level of the apical posterior segment of the RUL, representing a cavitating pulmonary TB lesion (thick black arrows).

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Fig. 3: MDCT-Coronal MIP reconstruction images in chest and lung window at the previous patient with TB. Erosion of a right pulmonary artery branch for the upper lobe leads to active extravasation (white arrow) and blood within the cavity.

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**Fig. 4:** MDCT- coronal and axial images, before and after MIP reconstruction in lung window, of a patient with NHL: presence of blood in the lobar bronchus for the RUL (black arrow) and a nodular infiltrate (diameter ~ 2.3 cm) with radial projections surrounded by an area of ground-glass opacification. The lesion is in contact with the adjacent pleura, presenting focal thickening. This finding was attributed to invasive aspergillosis and it was confirmed by biopsy.

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**Fig. 5:** MDCT-Axial and coronal MIP reconstruction images in lung and chest window, at a patient with AML, lung inflammation and hemoptysis. The examination showed hyperdense alveolar infiltrates surrounded by an area of ground glass opacity and hyperdense plugging (blood) at segmental and subsegmental bronchi for the RUL.

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Fig. 6: MDCT-Axial images in lung window showing cystic bronchiectasis, filled with blood at the RUL.

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Fig. 7: MDCT-Axial and coronal images in chest window shows: Extensive mass occupying the right pulmonary hilum with heterogenous contrast enhancement and craniocaudal diameter~ 14cm. The lesion extended to the anterior, middle and posterior mediastinum, encapsulating and possibly infiltrating the superior vena cava and brachiocephalic veins, the pulmonary artery (particularly the right main branch), the left atrium, right pulmonary veins, the esophagus, trachea and both stem and lobar bronchial branches of the right lung.

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Fig. 8: MDCT-Axial and coronal MIP reconstruction images, in chest and lung window. Mass lesion extending from the right lung hilum to the upper and middle mediastinum, infiltrating the middle lobe and the medial segment of the right lower lobe. It was not possible to separate the lesion from the concomitant lymph node swellings of the upper and middle mediastinum. There were also significant stenosis of the right main bronchus, obstruction of the middle lobar and the superior lobar bronchus of the RLL. Infiltration of the right main pulmonary artery, of the right pulmonary veins and a significant degree of stenosis with possible infiltration of the lower portion of the superior vena cava, were also depicted.

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Fig. 9: MDCT-Axial and coronal MIP reconstruction images, in lung and chest window shows: Mass lesion of the left hilum, that encapsulates deforms and infiltrates the left pulmonary artery, along with it's branches that corresponds to the left upper lobe and the lingula. It seems that left upper pulmonary veins are included.

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**Fig. 10:** MDCT- coronal axial and sagittal MIP reconstruction images, in chest window show: Dilated bronchial artery (black arrows) originating from the anterior wall of the descending aorta at the level of T7 passing through the mediastinum and whose final branches end up at the right middle lobe. The presence of ground glass opacifications and patchy infiltrates at the respective area (not shown here) were probably indicative of pulmonary hemorrhage, in a patient with hemoptysis.

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Fig. 11: MDCT-Axial and coronal MIP reconstruction images show: Small aneurysms of few millimeters in diameter, were observed at subsegmental branches of the pulmonary artery for the RUL (thin black and white arrows). It was recommended further investigation for underlying vasculitis. There was also presence of a minor arteriovenous dysplasia between a subsegmental pulmonary artery and vein of the RUL (red eclipse).

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**Fig. 12:** MDCT- coronal and axial, MIP reconstruction images, in the same patient show mild dilatation (up to 4mm) and tortuosity of the bronchial arteries (black arrows). Check again a small aneurysm of a subsegmental branch of the right pneumonic artery (green arrow), for the posterior segment of the RUL and multiple microaneurysms at subsegmental branches of the pulmonary artery for the RUL (red arrows).

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Fig. 13: MDCT-coronal and axial images before and after MIP reconstruction in chest window of a patient with pulmonary embolism (white arrows) and hemoptysis caused in the setting of generalized carcinomatosis.

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Fig. 14: MDCT- Axial and coronal MIP reconstruction images in lung window of a patient with pulmonary edema and hemoptysis.

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Fig. 15: MDCT- Coronal MIP reconstruction image in lung window of a patient with congestive heart failure, pulmonary embolism (not shown) and, hemoptysis.

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**Fig. 16:** MDCT- axial, MIP reconstruction images, in a heavy smocker patient, with cryptogenic hemoptysis. Distended segmental bronchi for the RUL filled with blood, surrounded by an area of ground glass opacity.

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Fig. 17: MDCT-Axial images in lung window, after and before MIP reconstruction. There is an active blood extravasation from a subsegmental branch of the right pulmonary artery corresponding to the RUL (black arrow), surrounded by a small area of ground glass opacity. The patient presented with hemoptysis and had no previous medical history, except that he was a smoker.

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Conclusion

Chest radiography although an excellent initial imaging test for evaluating hemoptysis, as quick and inexpensive method, in as many as 40% of cases of hemoptysis, the findings are normal or do not reveal the source of the bleeding. Consequently while a localizing finding on radiography is helpful, a normal one calls for further evaluation by other means, including conventional CT, multidetector CT angiography, or bronchoscopy.

On the other hand both conventional CT and multidetector CT angiography are quick and noninvasive ways to locate the site of bleeding, determine the cause of bleeding and create a map to guide further therapy.

MDCT in particular, provides high-resolution angiographic studies of the thoracic and upper abdominal vasculature, which are useful prior to anticipated bronchial or non bronchial artery embolization or surgical intervention.

However, while CT imaging is extremely useful in evaluating bleeding from larger vessels, it adds little information beyond that obtained by chest radiography in cases of diffuse alveolar hemorrhage [3,4].

There is controversy in the literature regarding the use of CT versus bronchoscopy when further study is indicated. Bronchoscopy, is useful in identifying a specific site of bleeding, diagnosing active hemorrhage, and controlling the airway in patients with catastrophic hemorrhage [2]. However, its capacity to help localize the site of bleeding is equivalent to that of radiography or CT, and it is less useful in detecting an underlying disease process [3]. The airways are often filled with blood at the time of bronchoscopy, making evaluation of the distal airways difficult [5].

According to the above mentioned, CT is superior to fiberoptic bronchoscopy in detecting the 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. In locating the site of bleeding, CT performs about as well as fiberoptic bronchoscopy [6].

Besides, several articles have cited cases of hemoptysis with negative chest radiograph and bronchoscopy in which CT subsequently showed malignancies. In addition, CT can establish the diagnosis of bronchiectasis and defines the extraluminal extent of lesion in relation to bronchi and mediastinal structures, optimizing bronchoscopic techniques.

Thirumaran et al., looked at 270 patients with hemoptysis and normal chest radiographs. Ninety percent of these patients were either active or ex-smokers. The authors found that 9.6% of patients in their study had respiratory tract malignancy, and CT detected 96% of them. They concluded that any patient with a history of smoking should have
further examination with CT regardless of the amount of hemoptysis or the appearance of a normal chest radiograph [7].

Herth et al, have reported that for smokers with hemoptysis of unknown origin who are >40 years of age, approximately 6% of them will have a lung cancer that manifests within 3 years. The authors recommend additional follow-up testing in patients presenting with hemoptysis in which the underlying cause was not detected at initial radiographic studies [1].

In certain cases, it may be useful or even necessary to perform follow-up CT several months after the episode of hemoptysis to study the evolution of underlying parenchymal lung abnormalities or to exclude the possibility that a small malignancy may have been missed at initial CT.

In addition and according to resent literature diagnostic angiography does not identify the source of bleeding as well as CT does. It is important to locate the bleeding site first via CT, multidetector CT angiography, or bronchoscopy. Diagnostic angiography can be time-consuming. The procedure time can be significantly shorter if CT, bronchoscopy, or both are done first to ascertain the site of bleeding before bronchial artery embolization. Another reason that performing CT first is important is that it can rule out situations in which surgery would be preferred over bronchial artery embolization [4].

In the present study, we have prospectively followed a Greek cohort of patients admitted to a University Hospital and evaluated the relative frequency of different causes of hemoptysis and the diagnostic value of MDCTA.

MDCTA suggested the thoracic vasculature as a bleeding mechanism, in 17,8% of the cases, with the involvement of varicose pneumonic veins in one patient, dilatation of the bronchial arteries, due to different causes in 6 patients, pulmonary sequestration and vascular dysplasia, in two patients.

The bronchial circulation supplies blood flow to the bronchial wall. In bronchiectasis, chronic airway inflammation causes hypertrophy and tortuosity of the bronchial arteries that accompany the regional bronchial trees, as well as expansion of the submucosal and peribronchial plexus of blood vessels. Rupture of either the tortuous vessels or the capillary plexus results in rapid bleeding because these blood vessels are subjected to systemic blood pressure [8]. Peripheral pulmonary artery pseudoaneurysms occur in up to 11% of patients undergoing bronchial angiography for hemoptysis [9].

Study of the lung parenchyma and mediastinum revealed acute infection in 15 cases (one patient with TB), lung carcinoma in ten cases, including metastasis, cardiogenic pulmonary edema in 7 cases and bronchiectasis in only 5 cases. MDCTA was not diagnostic as regard the cause, in 6 patients (11,7%), except from hazy consolidations or ground glass infiltrates, representing intra-alveolar hemorrhage (cryptogenic).
Although this study gives a good idea of the etiology of hemoptysis in our group, it is limited by its retrospective nature. Furthermore, the evaluation and therapeutic decisions were not based on a preset protocol but rather on the clinical experience of each attending physician. It showed that acute infection is the leading cause of hemoptysis, followed by lung malignancy and bleeding from thoracic vasculature, while in comparison with previously performed (older than 20 years) studies, the percentage of bronchiectasis was significantly lower only 5%. The last finding is justified because of the widespread use of antibiotics that have limited chronic infections.

Multidetector CT (MDCT) angiography is an important potential diagnostic modality for the accurate and prompt diagnosis of the underlying lung parenchymal and vascular disorder that leads to hemoptysis. The mapping and the depiction of vascular structures 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.
References