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Comparison of MDCT and DSA in identification of the culprit vessels in haemoptysis

Mekala Uday[1], Pankaj Sharma[2*], Girish Sindhwani[3], Ruchi Dua[3], Udit Chauhan[2]
[1] Department of Radiodiagnosis, All India Institute of Medical Sciences Rishikesh, Rishikesh, Uttarakhand, India
[2] Professor, Department of Radiodiagnosis, All India Institute of Medical Sciences Rishikesh, Rishikesh, Uttarakhand, India
[3] Professor, Department of Pulmonary Medicine, All India Institute of Medical Sciences Rishikesh, Rishikesh, Uttarakhand, India

Abstract

Background

Most of studies evaluating the usefulness of MDCT angiography prior to DSA in managing haemoptysis, were conducted in Western world, where the main cause of haemoptysis is bronchogenic carcinoma; as compared to Indian subcontinent, where the main cause of haemoptysis is tuberculosis. In literature, most of studies which determined usefulness of MDCT angiography were retrospective in nature, and only very few studies reported the diagnostic accuracy of MDCT angiography. Our study is a prospective study done in Himalayan belt of North India, with most common cause of haemoptysis being tuberculosis; and in this study we have tried to evaluate the diagnostic accuracy of MDCT angiography in patients in whom BAE was done for management of haemoptysis.

Aim and Objective

The aim of current study is to prospectively assess the diagnostic accuracy of MDCT angiography before BAE, for management of patients with haemoptysis, in Himalayan belt of North India.

Material and Method

101 patients were recruited in this prospective study, done over a period of 18 months. MDCT angiography was performed in all these patients, prior to BAE. MDCT angiography findings were recorded in these patients, and compared with DSA findings.

Observation and Result

When we compared MDCT angiography with DSA for detecting culprit vessels responsible for haemoptysis, we found sensitivity as 97.73%, specificity as 100%, positive predictive value as 100%, negative predictive value as 67.85% and diagnostic accuracy as 97.84%.

Conclusion

MDCT angiography is a highly sensitive and specific investigation, that can be used for comprehensive evaluation of pathological bronchial and non-bronchial vessels, and provides a detailed road map before proceeding to BAE. DSA is superior to MDCT angiography to detect culprit vessels. Our study validated that there was no discernible difference in angiographic results between patients with or without tuberculosis. One right bronchial artery and one left bronchial artery (Cauldwell type II) was the most common branching pattern of bronchial artery, followed by two right (one ICBT and one bronchial) arteries and one left bronchial artery (Cauldwell type IV).

Keywords: Hemoptysis, multidetector computed tomography angiography, bronchial artery, bronchial artery embolization, digital subtraction angiography

Introduction

Haemoptysis is defined as the expectoration of blood, originating from lungs or airways of lower respiratory tract [1]. It can range from just blood tinged sputum to severe haemorrhage, which can be life threatening [2, 3]. It is a common presenting symptom in a wide variety of diseases, ranging from infection to malignancy [4]. The underlying cause of massive haemoptysis varies between the Western and non-Western population. In non-western world, one of the most common cause of massive life threatening haemoptysis is pulmonary tuberculosis [5, 6, 7]. In contrast, the cause in Western world is mostly bronchogenic carcinoma, and chronic inflammatory lung disease due to bronchiectasis, cystic fibrosis, or aspergillosis [1, 5].

Without timely diagnosis and management, haemoptysis can be life threatening [8]. In most of cases (around 90%), the major source of haemoptysis is bronchial circulation, followed by pulmonary circulation [8, 9, 10]. The mortality rate from massive haemoptysis is usually greater than 50%, if treated conservatively. In addition, most of these patients are not surgical candidates, due to their inadequate pulmonary reserve, or due to other medical condition [11, 12]. Hence, for treating massive haemoptysis, endovascular embolization has found to be the most efficient, and least intrusive management technique [13]. Knowledge of culprit vessel before embolization helps interventional radiologist, as it drastically reduces procedure time, and thereby reduces radiation exposure. Also, nearly 30% of bronchial arteries show ectopic origin, and knowledge of vascular anatomy before embolization, significantly improves technical success rate of bronchial artery embolization (BAE).

In clinical setting of haemoptysis, Multidetector Computed Tomography (MDCT) angiography is a non-invasive imaging tool, that permits thorough evaluation of lung parenchyma, airways, and thoracic vessels.[13] Most of studies evaluating the usefulness of MDCT angiography prior to DSA in managing haemoptysis, were conducted in Western world, where the main cause of haemoptysis was bronchogenic carcinoma, as compared to Indian subcontinent, where the main cause is generally tuberculosis [5]. In literature, most of studies in Indian sub-continent which determined usefulness of MDCT angiography were retrospective in nature with less sample size and only very few studies reported the diagnostic accuracy of MDCT angiography. As reported in literature, spinal cord infarction, bronchial infarction, oesophago-bronchial fistula are the major complications of BAE, with very less incidence rates [14, 15]. Chest pain, fever, dysphagia are minor complications of BAE [14, 16]. The most common complication after BAE is chest pain [17]. Our study is a prospective study done in Himalayan belt of North India, with most common cause of haemoptysis being tuberculosis, and in this study we have tried to evaluate the diagnostic accuracy of MDCT angiography in patients in whom BAE was done for management of haemoptysis.

Aim and objective

The aim of current study is to prospectively assess the diagnostic accuracy of MDCT angiography before BAE, for management of patients with haemoptysis, in Himalayan belt of North India.

Material and method

This prospective observational study was conducted in AIIMS Rishikesh after obtaining clearance from Institute research board and Institute Ethics Committee (AIIMS/IEC/21/646, dated 26/11/2021). 101 patients were recruited in this prospective study based on the inclusion and exclusion criteria, after taking written informed consent. Patients with clinically significant haemoptysis were included in the study, where as patients with renal insufficiency, uncorrected coagulopathic disorders, history of contrast allergy, and hemodynamically unstable patients were excluded. MDCT angiography was performed in all these patients, prior to BAE. MDCT angiography findings were recorded in these patients and compared with DSA findings.

MDCT angiography

MDCT angiography was performed with 64 slice CT machine (Philips, protocol: 120 kVp, 300 mAs, 0.9 mm section thickness) or with 128 slice CT machine (Siemens, protocol: 120 kVp, 240 mAs, 0.9 mm section thickness). In supine position, patients were scanned from lung apex to the diaphragm. 80 to 100 ml of intravenous iodinated contrast material (Omnipaque 300 mgI/ml) was injected at rate of 4 ml/s, followed by 50 ml saline flush. A circular zone of interest, at level of descending thoracic aorta, was used in automatic bolus triggering software. Data acquisition was initiated at 100 Hounsfield unit level of triggered contrast enhancement (HU). At 1 mm section thickness and 0.6 mm increments, a series of images were acquired. The entire MDCT angiography data set was moved to workstation for post-processing. Abnormal culprit vessels were identified and features like number, origin, ostia position, diameter and course of vessel were evaluated and analysed.

Bronchial artery were identified as abnormal based on following features:

- Diameter greater than 1.5 mm,
- Tortuous course,
- Parenchymal staining,
- Broncho-pulmonary shunt, or
- Active contrast extravasation.

Non bronchial systemic arteries were considered abnormal, if they were dilated or tortuous or showed parenchymal staining.

We also evaluated the lung parenchymal findings, causative for haemoptysis.

BAE

In all patients, we did conventional digital subtraction angiography (DSA), followed by super-selective embolization of culprit vessels. First, a 5 Fr vascular sheath was inserted into common femoral artery using Modified Seldinger technique. Pre-procedural MDCT angiography provided prior knowledge and road map of the vasculature, which helped to carry out super-selective catheterisation of abnormal vessel. Super-selective embolization was done in vessels which showed any of following feature: diameter more than 1.5 mm, tortuous course, shunting into pulmonary vasculature, parenchymal staining or active contrast extravasation. We recorded the characteristics of abnormal bronchial and non-bronchial vessels. MDCT angiography findings were finally compared with DSA findings.

Statistical analysis

Data was coded and recorded in MS Excel spreadsheet. SPSS v27 (IBM Corp.) was used for data analysis. Descriptive statistics: Categorical variable were expressed in frequency and proportion. Inferential statistics: Independent sample t-test, sensitivity and specificity test were used to compare proportions.

Observation and result

Total 101 patients were enrolled in this study, with mean age of 46.58 years, and standard deviation of 16.65. 75 (74.26%) patients were males and 26 (25.74%) patients were females. Most common aetiology of haemoptysis was tuberculosis (active and old) in 69 (65.3%) patients, followed by bronchiectasis in 12 (13.8%) patients, and aspergilloma in 10 (9.9 %) patients. Other aetiology of haemoptysis was pneumonia in 5 (4.9%) patients, lung cancer in 3 (2.12%) patients, and cystic fibrosis in 2 (1.98%) patients.

Cavitary lesions were most common lung findings, noted in 77 (76.2%) patients; with 45 (58.44%) patients showing right sided changes, 42 (54.54%) patients showing left side changes, and 10 (12.98%) patients showing bilateral side cavitary change.

Bronchiectasis was seen in 26 (25.74%) patients, with 18 (69.23%) patients showing right sided changes, 17 (65.38%) patients showing left side changes, and 9 (34.61%) patients showing bilateral side cavitary change.

Pleural thickness of more than 3 mm was seen in 37 patients on right side, and 31 patients on left side. 26 out of 37 (70.27%) patients had non-bronchial arterial supply, with right pleural thickness more than 3mm, with sensitivity of 78.7%, specificity of 83.8%, positive predictive value of 70.2%, and negative predictive value of 89%. 21 out of 31 (70.27%) patients had non-bronchial arterial supply, with right pleural thickness more than 3mm, with sensitivity of 80.7%, specificity of 86.6%, positive predictive value of 67.7%, and negative predictive value of 92.8%.

MDCT angiography findings (Figure 1, 2a, 3, 4a)

Total of 141 right bronchial arteries were visualized in 101 patients. One right bronchial artery was noted in 63 (62.37%) patients, two right bronchial arteries was noted in 36 (35.64%) patients, and three right bronchial arteries was noted in 2 (1.98%) patients. Average number of bronchial arteries per patient was 1.39.

One hundred and eight (108) right bronchial arteries showed orthotopic origin (76.59%), and 33 right bronchial arteries showed ectopic origin (23.40%). One hundred and One right bronchial arteries showed origin from inter-costo-bronchial trunk (ICBT) (71.63%), 13 right bronchial arteries showed origin from common bronchial trunk (9.21%), 17 right bronchial arteries showed direct origin from descending thoracic aorta (12.05%), and 11 right bronchial arteries showed origin from right subclavian artery (7.80%). Mean diameter of right bronchial artery was 2.4 mm.

Vertebral level of right bronchial artery was D2 level in 6 arteries, D3 level in 6 arteries, D4 level in 13 arteries, D5 level in 31 arteries, D5-D6 intervertebral disc level in 99 arteries, D6 level in 29 arteries, and D7 level in 7 arteries. Ostia (clock position) of right bronchial artery was 6 O'clock position in 3 arteries, 7 O'clock position in 4 arteries, 8 O'clock position 17 arteries, 9 O'clock position in 37 arteries, 10 O'clock position in 31 arteries, 11 O'clock position in 28 arteries, 12 O'clock position in 19 arteries, and 1 O'clock position in 2 arteries. Total 124 right bronchial arteries were identified as abnormal on MDCT angiography.

Total of 129 left bronchial arteries were visualized in 101 patients. One left bronchial artery was noted in 74 (57.36%) patients, two left bronchial arteries was noted in 26 (20.15%) patients, and three left bronchial arteries was noted in 1 (0.77%) patient. Average number of left bronchial arteries per patient was 1.27. 104 left bronchial arteries showed orthotopic origin (80.62%) and 25 left bronchial arteries showed ectopic origin (19.37%). 13 left bronchial arteries showed their origin from common bronchial trunk (10.07%), 102 left bronchial arteries showed direct origin from descending thoracic aorta (79.06%), 3 left bronchial arteries showed origin from left internal mammary artery (2.32%), 7 left bronchial arteries showed origin from left subclavian artery (5.42%), 3 left bronchial arteries showed origin from arch of aorta (2.32%). Mean diameter of left bronchial artery was 2.2 mm.

Vertebral level of left bronchial arteries was D2 level in 4 arteries, D3 level in 7 arteries, D4 level in 11 arteries, D5 level in 36 arteries, D5-D6 intervertebral disc level in 39 arteries, D6 level in 29 arteries, and D7 level in 3 arteries. Ostia (clock position) of left bronchial artery was at 9 O'clock position in 7 arteries, 10 O'clock position in 9 arteries, 11 O'clock position in 21 arteries, 12 O'clock position in 38 arteries, 1 O'clock position in 28 arteries and 2 O'clock position in 26 arteries. Total 118 left bronchial arteries were identified as abnormal on MDCT angiography.

One right bronchial artery and one left bronchial artery configuration was seen in 45 (44.5%) patients. Two right bronchial arteries and one left bronchial artery configuration was recorded in 27 (26.7%) patients. One right bronchial artery and two left bronchial arteries configuration was recorded in 17 (16.8%) patients. Two right bronchial arteries and Two left bronchial arteries configuration was recorded in 9 (8.9%) patients. Three right bronchial arteries and one left bronchial artery configuration was recorded in 2 (1.98%) patients. One right bronchial artery and Three left bronchial arteries configuration was recorded in 1 (0.99%) patient.

On right side, 84 non-bronchial systemic arteries (NBSA) were recorded and the frequency of vessels is depicted in Table 1. Most common site of origin of NBSA on right side was from subclavian artery, followed by intercostal and internal mammary artery. On left side, 61 NBSA were recorded and the frequency of vessels is depicted in Table 1. Most common site of origin of NBSA on left side was from internal mammary artery, followed by subclavian and intercostal artery.

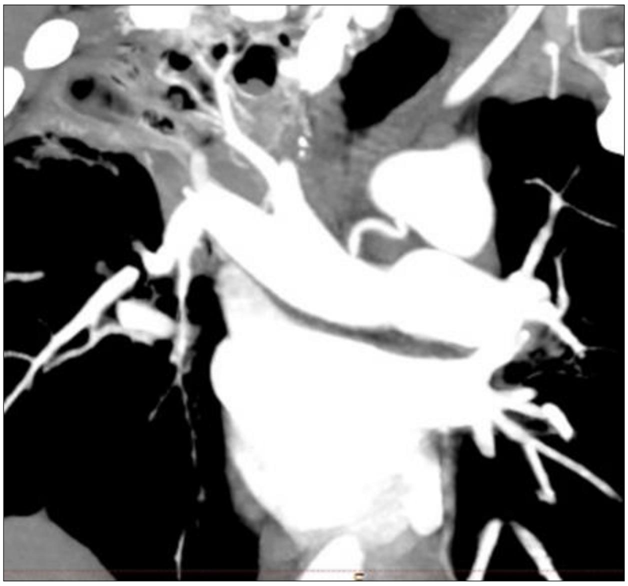

Fig 1: Coronal MIP CECT image of a 32 year old male patient with complaints of hemoptysis showing ectopic origin of left bronchial artery from arch of aorta

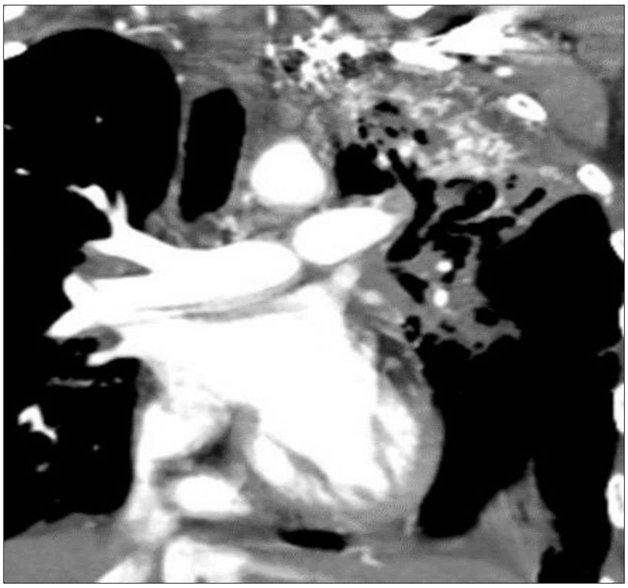

Fig 2 a: Coronal CECT image of a 31 y old female with past history of tuberculosis depicting multiple vessels arising from left subclavian artery supplying diseased areas of upper lobe of left lung

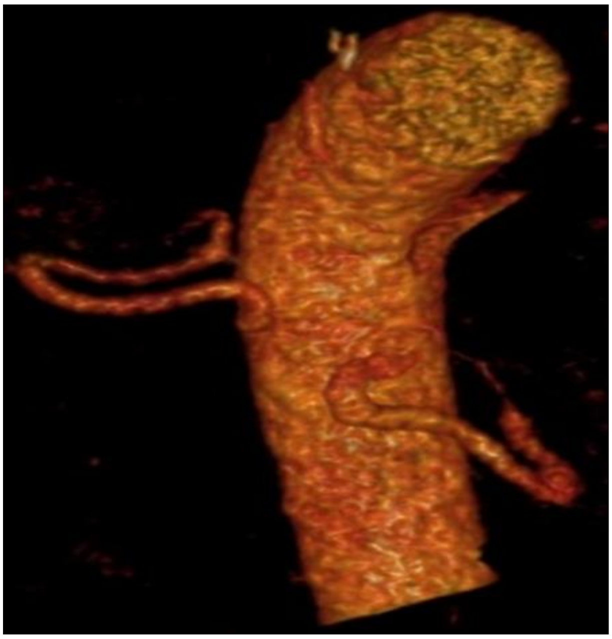

Fig 3: 3D reformatted image showing right and left bronchial arteries arising from descending thoracic aorta

Following images are of a 40 year old male with reactivation tuberculosis who presented with complaints of haemoptysis since 2 months.

Fig 4a: Axial CECT image showing multiple feeder vessels from left lateral thoracic artery supplying diseased left upper lobe

Table 1: Non-bronchial systemic arteries on MDCT angiography

Right side NBSA origin	Percentage	Left side NBSA origin	Percentage
Internal mammary artery	26.19	Internal mammary artery	29.50
Inferior phrenic	4.76	Inferior phrenic	6.55
Intercostal arteries	29.76	Intercostal arteries	24.59
Peri-cardiophrenic artery	2.38	Left gastric artery	3.27
Subclavian artery	32.10	Subclavian artery	26.20
Thyrocervical trunk	4.76	Thyrocervical trunk	9.83

DSA Findings (Figure 2b, 4b, 4c)

Four hundred and seventeen (417) arteries were visualised by DSA including both bronchial and NBSA, out of which 398 arteries were found to be abnormal. Total 244 abnormal bronchial arteries were seen, with 230 (94.2%) arteries showing tortuous course, and 220 (90%) arteries showing parenchymal staining. Shunting from left subclavian artery into left pulmonary artery was noted in 2 patients. Supply was seen from 145 NBSA; with 136 (93.7%) arteries showing parenchymal staining. 71 (29%) arteries showed bronchopulmonary shunting. Rasmussen aneurysm was seen in 3 patients.

Total culprit arteries on MDCT angiography vs total culprit arteries on DSA is depicted in Table 2. 389 arteries including bronchial and NBSA were noted to be abnormal on both MDCT angiography and DSA. 9 bronchial arteries were detected as normal on MDCT angiography, but these vessels were abnormal on DSA. Out of these 9 vessels which were normal on MDCT angiography, 5 showed parenchymal blush and 4 showed bronchopulmonary shunting on DSA. 19 bronchial arteries were detected as normal on both CT angiography and DSA.

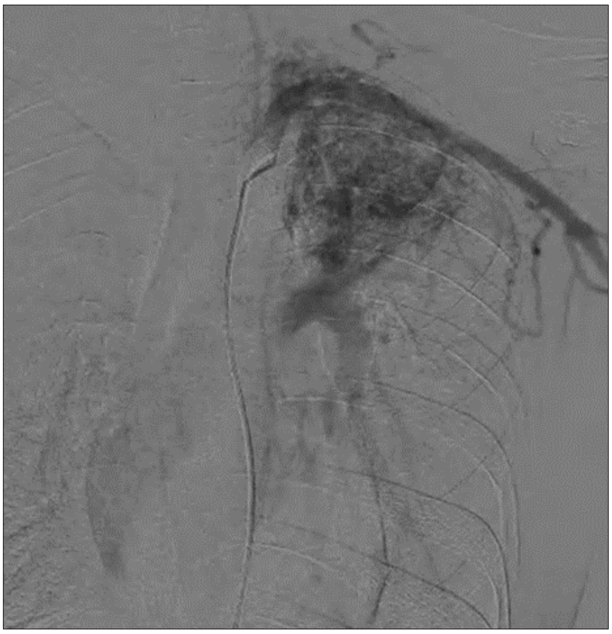

Fig 2 b: Digital subtraction image of same patient after left sub clavian artery catheterization - showing parenchymal staining in left upper lobe with shunting between branches of left sub clavian artery and upper lobe branches of left pulmonary vei

Fig 4b: DSA image showing abnormal tortuous feeding vessels from left internal thoracic artery, with parenchymal blush

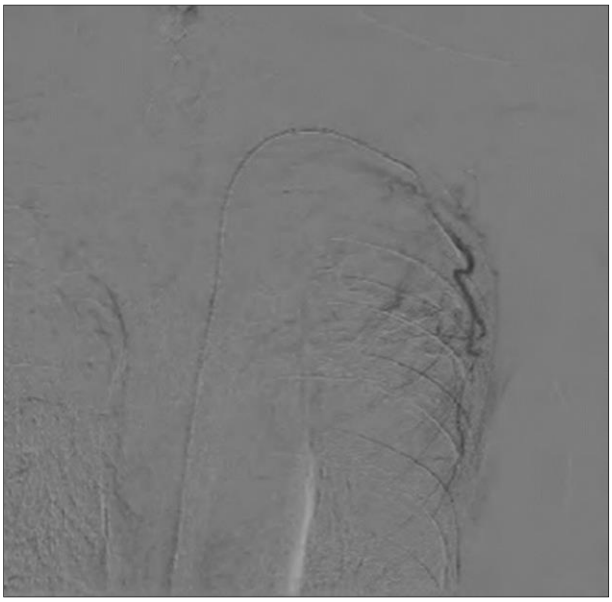

Fig 4c: Post embolization image of same patient

Table 2: Comparison of MDCT and DSA

		Culprit arteries on DSA		Total
		Yes	No	
Culprit arteries on MDCT Angiography	Yes	389 (TP)	0 (FP)	389
	No	9 (FN)	19 (TN)	28
Total		398	19	417

Sensitivity =TP/(TP+FN)=389/398=0.9773 (97.73%)
Specificity=TN/(TN+FP)=19/19=1 (100%)
Positive Predictive Value=TP/(TP+FP)=389/389=1 (100%)
Negative Predictive Value=TN/(FN+TN)=19/28=0.6785 (67.85%)
Diagnostic accuracy=TP+TN/(TP+ TN+FP+FN)=408/417= 0.9784 (97.84%)

Discussion

This study was carried out to determine the diagnostic accuracy of MDCT angiography in comparison to DSA in haemoptysis patients, before bronchial artery embolization in Himalayan belt of North India. A total of 101 patients were enrolled. Mean age of patients with haemoptysis was 46.5 years. Most of individuals were male (74.5%), with male: female ratio of 3:1.

In our study, the most common cause of haemoptysis was cavitary disease due to tuberculosis (64.3%). Bhalla *et al*, in their study reported that in Indian context, tuberculosis is most common cause of haemoptysis. Similarly, other studies also reported same findings with tuberculosis as more common association in South-East Asian countries, whereas bronchogenic carcinoma was most common cause in Western world [1, 5, 7, 18].

According to published literature so far, the main source of haemoptysis is bronchial circulation; with variable number and location of bronchial arteries in each patient [5, 13, 19]. In our study, we detected on average 1.39 bronchial artery on right side, and 1.27 bronchial artery on left side, by MDCT angiography. The most common origin of right bronchial artery was from ICBT (71.6%), followed by common bronchial trunk origin (9.2%), direct origin from descending thoracic aorta (12%), and from right subclavian artery (7.09%). The most common origin of left bronchial artery was directly from descending thoracic aorta (79%), followed by common bronchial trunk origin (10.8%), left subclavian artery (5.4%), left internal mammary artery (2.3%) and arch of aorta (2.3%). These results are in line with earlier published studies, which reported ICBT as most common site of origin of right bronchial artery, and descending thoracic aorta as most common site of origin of the left bronchial artery [20, 21, 22].

Thrity three (33) out of 141 (23.40%) bronchial arteries on right side showed ectopic origin, whereas 26 out of 129 (20.15%) bronchial arteries on left side showed ectopic origin. These results are in line with the previous studies, where they reported percentage of ectopic bronchial vessels ranged from 8.3-56% [23, 24, 25].

Cauldwell *et al*, in 1948 published first study which described patterns of branching of bronchial artery; and their classification is currently the most widely used classification system [19, 26]. According to Cauldwell *et al*, 1 right bronchial artery and 1 left bronchial artery was the most common branching pattern [21]. In our study (Table 3), we found that the most common type of bronchial artery configuration was 1 right ICBT and 1 left bronchial artery (Cauldwell type II) (44.5%); followed by 2 right (one ICBT and one bronchial) arteries and 1 left bronchial artery (Cauldwell type IV) (26.7%); 1 right ICBT and 2 left bronchial arteries (Cauldwell type I) (16.8%); 2 right (one ICBT and one bronchial) arteries and 2 left bronchial arteries (Cauldwell type III) (8.9%).

Bronchial artery ostia position on right side was most commonly from 9 O'clock to 11 O'clock position (68%); whereas ostia position on left side was most commonly from 11 O'clock to 1 O'clock position (67.4 %). According to these observations, majority of right bronchial artery arise in medial wall of descending aorta, whereas majority of left bronchial artery arise in anterior wall of descending aorta. These findings are consistent with previous published studies [20, 21, 22, 27].

The direct selective catheterization of an aberrant NBSA, near the bleeding location was made possible by MDCT angiographic findings. According to these findings, bronchial and NBSA embolization can be planned in a targeted and effective manner, with aid of MDCT angiography, as reported with previous studies [18, 28]. MDCT angiography findings were correlated with DSA findings, and analysed for diagnostic accuracy. Total 389 vessels including bronchial and NBSA were detected as abnormal by MDCT angiography. 9 arteries were missed on MDCT angiography, but were picked on DSA. Total 398 vessels were detected as abnormal on DSA. 19 vessels were normal, both on MDCT angiography, and on DSA. When we compared MDCT angiography with DSA for detecting culprit vessel responsible for haemoptysis, we found sensitivity as 97.73%, specificity as 100%, positive predictive value as 100%, negative predictive value as 67.85%, and diagnostic accuracy as 97.84%.

The effectiveness of MDCT angiography for BAE pre-procedural planning was published by Remy-Jardin *et al*, who showed 86% concordance rate for detecting 58 aberrant culprit vessels on MDCT angiography, as compared to gold standard DSA [29]. Huu Y le *et al*, reported that MDCT angiography had 97.5% diagnostic accuracy in detecting culprit vessel, responsible for haemoptysis [30].

In our study, average bronchial artery per patient were found to be 2.3 in non-tubercular patients, and 2.39 in tubercular patients. Most common type of bronchial artery configuration was 1 right bronchial artery and 1 left bronchial artery, in both tubercular and non-tubercular patients. Ectopic bronchial arteries were noted in 25 % of non-tubercular, and 26.9 % of tubercular patients. It was also noted that there was statistically no significant difference in mean diameter of bronchial artery in tubercular, and non-tubercular patients. All these findings conclude that there is no difference in major characteristics of bronchial vessels in tubercular, and non-tubercular patients.

Table 3: Branching pattern of bronchial arteries in patients with haemoptysis

Branching pattern	Number of patients
One right, One left	45
One right, Two left	17
One right, Three left	01
Two right, One left	27
Two right, Two left	09
Three right, One left	02

Limitations

Our study was a single centre study, with inclusion of 101 patients. No follow up was done after embolization for status of early recurrence of haemoptysis. Moreover, only few malignancy patients were included in sample population, and that too from limited geographical region.

Conclusion

Our study validated that the diagnostic accuracy of MDCT angiography in detecting culprit vessels in haemoptysis is approximately 97.8% compared to DSA which is gold standard. MDCT angiography is a highly sensitive and specific investigation, that can be used for comprehensive evaluation of pathological bronchial and non-bronchial vessels, and provides a detailed road map before proceeding to BAE.

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