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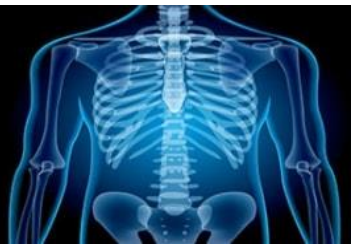

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Role of multi detector computed tomography (MDCT) angiography in the management of patients with haemoptysis

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Abstract
Haemoptysis is one of the deadliest symptoms of respiratory illness. Identifying the etiology and source of haemoptysis plays a crucial role in early diagnosis and planning for appropriate management. The aim of the study was to evaluate the role of MDCT angiography in identifying the site, cause and source of haemoptysis along with determining the normal variants of bronchial arteries. A prospective study was performed on 50 patients with complaints of haemoptysis for a period of 18 months. MDCT angiography was performed to interpret site and source of bleed. Tuberculosis (44%) was the most common underlying cause of haemoptysis in a cohort of 50 patients. In most patients, bronchial artery was adjudged to the source of haemoptysis (72%), followed by the pulmonary artery. Non bronchial systemic arteries contributed to haemoptysis in 12% of patients. A total of 145 bronchial arteries were detected, out of which 75 were right bronchial arteries (51%) and 71 left bronchial arteries (49%). The combination of 2 right bronchial arteries and 1 left bronchial artery was the most common (18%) branching pattern in this study. MDCT angiography is a robust diagnostic tool that permits visualisation of pulmonary vasculature involved in haemoptysis, thereby effectuating suitable treatment in time, and possibly reduce associated mortality rates.

Keywords: angiography, bronchial artery, haemoptysis, multi detector computed tomography (MDCT)

Introduction
Haemoptysis is characterized by the expectoration of blood from the lower respiratory tract and serves as a cogent indicator of underlying diseases capable of causing high morbidity and mortality [1]. Common etiological factors for haemoptysis include fatal diseases such as tuberculosis, bronchiectasis, aspergilloma, and bronchogenic carcinoma [2]. Haemoptysis of unidentified causes are also noticed in 15–30% of all cases and is referred to as cryptogenic hemoptysis [3]. Hence, an expeditious and comprehensive investigation of the lung airways, parenchyma, and thoracic vasculature becomes a prerequisite in the management of haemoptysis [1].

Severity of haemoptysis is classified into four types based on the rate of bleeding [4]. Mild haemoptysis is understood as blood loss below 50 ml/day, whereas expectoration between 50-20 ml/day and above 200 ml/day are identified as moderate and severe haemoptysis. Massive haemoptysis is the expectoration of over 300 ml/day [5-8]. Expectoration of such large volumes of blood, can result in asphyxiation by inundation of the airways. Mortality caused by such a phenomenon outnumbers that owing to blood loss [9]. Hence a functional definition of massive haemoptysis 'as an amount sufficient to cause life threatening complication' should be used to decide the appropriate line of management.[8]Mild or moderate hemoptysis is managed conservatively in most patients, with severe and massive forms of haemoptysis usually requiring surgical intervention [10].

Decrease or occlusion of pulmonary circulation occurring in acute and chronic lung diseases, gives way for proliferation and enlargement of bronchial arteries. This haphazard growth in bronchial arteries increases the susceptibility of the vessels to erosion by pathogens or rupture due to high pressure, ultimately extravasating into the respiratory tree [8].

Currently bronchial arterial embolism has been established as the therapeutic option of choice [10]. With the advent of technologically superior diagnostic tools like MDCT, it has

become possible to take a closer look at the manifestations of haemoptysis, high resolution mapping of thoracic and upper abdominal vasculature and pinpointing the bleeding site [1, 10]. Visualization of the exact site of bleed can increase the success rates of bronchial arterial embolism and surgery [10]. The insights obtained from MDCT analysis can serve as a guide in the subsequent management of the condition in patients. Hence the need for this study.

Aim and objective

To evaluate the role of MDCT angiography in identifying the etiology, source and site of bleeding in patients with haemoptysis along with mapping the variants of bronchial arteries.

Methods

This descriptive study was conducted over a period of 18 months i.e. from January 2018 to June 2019 at a tertiary care center. Patients of 18 years of age and above complaining of hemoptysis were included in the study. A total of 50 patients were selected via consecutive sampling method. Prior approval for this research was taken from the institutional ethics and research committees. Written informed consent was obtained from the patients before initiating the study.

Medical history of patients was documented, ensued by a physical examination. Patients having acquired at least 4-6hours of fasting status were prepped for an MDCT angiography. The MDCT angiography was performed using a Wipro GE optima 660 128 slice CT machine. The imaging parameters were as follows: beam width-40mm; beam pitch-39 -37mm/rot; and reconstruction thickness to 0.6-5 mm at 120 kV. Test dose of 0.5ml was given to each patient who was then observed for few minutes to look for any reactionary changes at the injection site. Subsequently, 1.5ml/kg (4-5ml/sec) of nonionic contrast agent (omnipaque) was administered IV via an automated injector device through an 18-gauge IV catheter. A region of interest was placed on the superior vena cava and bolus tracking method was applied. On reaching a density of 100HU, in 6 seconds craniocaudal scanning began from the lung apex to the lung base for pulmonary phase, immediate caudocranial scanning for aortogram phase was also done. The entire imaging was performed with the patient in the supine position at maximal inspiration during a single breath-hold. The protocol for MDCT is detailed in Table 1.

MDCT Protocol

Table 1: Technical specifications for MDCT

Feature	Specification
Scanner type	Multi detector row scanner
Detector coverage	40 mm
Kvp	120Kv
mAs	150 – 300mAs
Reconstructed slice thickness	0.6 mm to 5 mm
Pitch and speed	0.984: 1/ 39 - 37 (mm/rot)
Rotation time	0.8 s
Injector	Medrad stellant dual chamber power injector
Contrast injection rate	4.5 ml/sec of contrast, 300 mg I/ml, For a dose of 1.5 ml/kg of body weight

The lung parenchyma and mediastinum were analysed to look for mainly mass lesions, cavities, bronchiectasis and chronic parenchymal diseases. Site of the bleed in lungs was localized through two major signs in the lung parenchyma—*viz*., ground glass opacities, alveolar consolidation. Images showing extravasation of contrast medium into a bronchus or intrapulmonary shunting were also identified as bleeding site. To identify the vessel causing haemoptysis; bronchial, pulmonary and non-bronchial systemic arteries were analysed throughout their course. The study design is summarized in Figure 1.

Patient data such as name, age, sex, hospital number and imaging findings were collected, stored in Microsoft excel sheet. Frequency and percentage were used for analysis of categorical variable using SPSS V22.

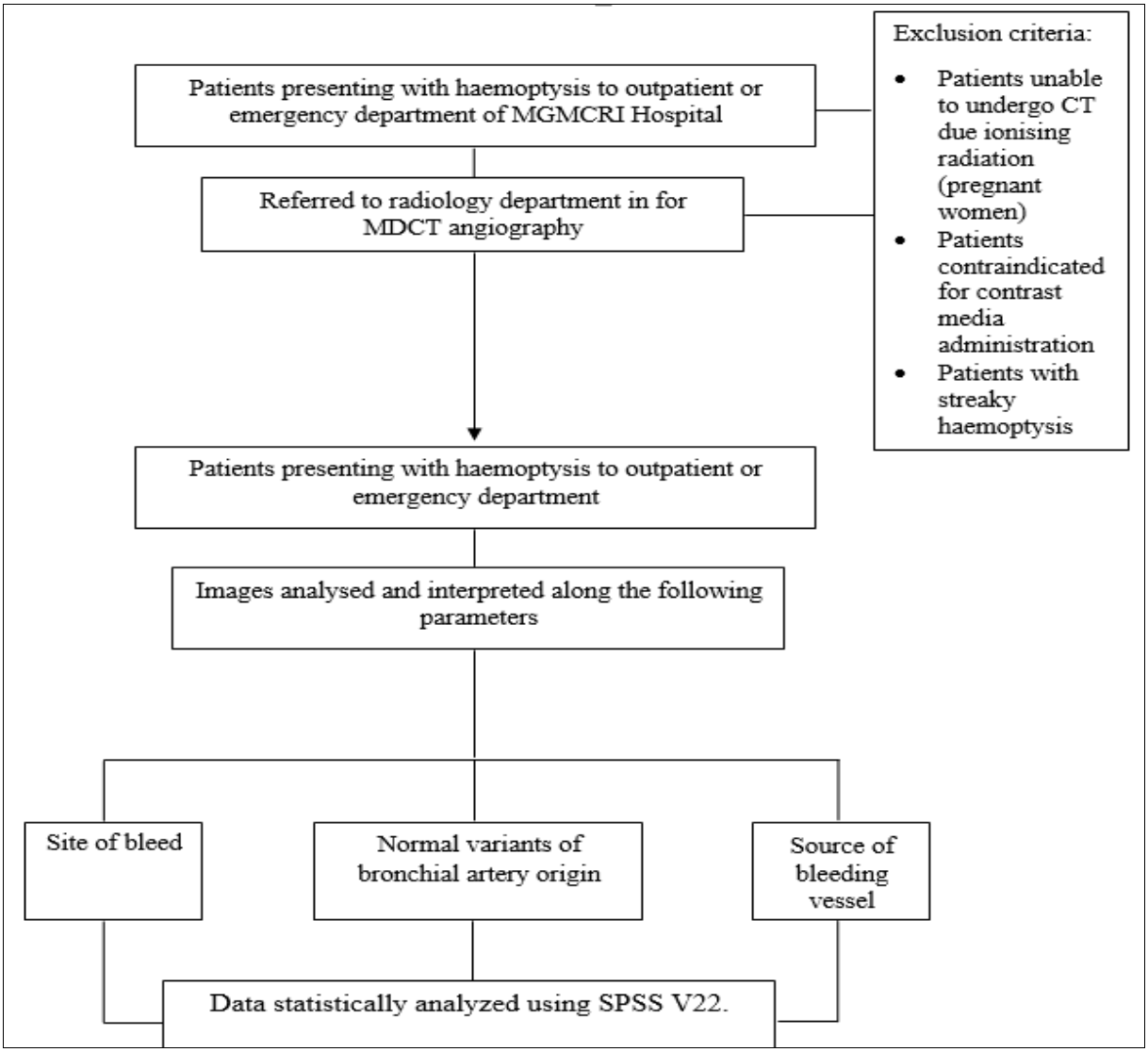

Fig 1: Sequential methodology of study

Results

A total of 50 participants were included in this study. The mean age of the cohort was 54.78 years, ranging between 19 to 77 years. Among whom, patients aged above 60 years of age (44%) were more predisposed towards developing haemoptysis (Figure 2). Male preponderance was noticed across the study cohort of haemoptysis patients, with males constituting 76% of the participants. [Table 2]

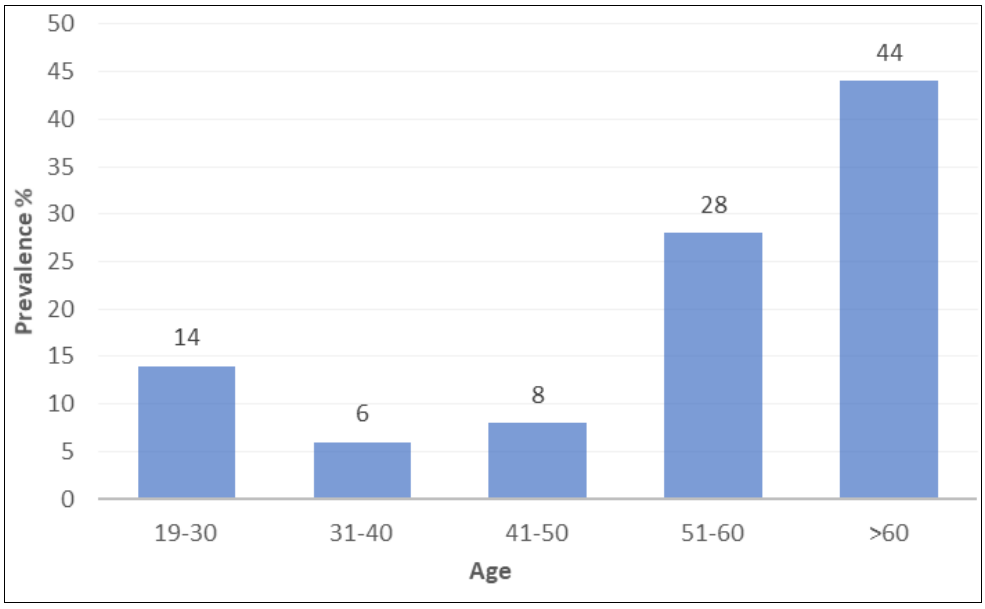

Fig 2: Age distribution across the study cohort

Of the total 50 patients, tuberculosis (46%) was found to be the most common underlying cause of haemoptysis. [Figure 3]

Table 2: Etiology of haemoptysis in patient studied (n=50)

Etiology	Frequency	Percent
Tuberculosis	23	46.0
Bronchiectasis	10	20.0
Carcinoma	8	16.0
Pneumonia	2	4.0
Aspergilloma	2	4.0
Metastasis	2	4.0
Empyema Necessitans	1	2.0
Lung Abscess	1	2.0
Pulmonary Hypertension	1	2.0
Total	50	100.0

Out of 50 patients, a majority of patients i.e. 46% presented with mild haemoptysisclosely followed by moderate haemoptysis (44%). Figure 3 delineates the different grades of haemoptysis as observed across the cohort.

Table 3: Grading of haemoptysis

Grading of haemoptysis	Frequency	Percent
Mild	23	46
Moderate	22	44
Severe	4	8
Massive	1	2
Total	50	100.0

Among a cohort of 50 patients, the site of haemoptysis for 31 (62%) patients was the right lung in which 42% cases was from upper lobe, 16% cases from middle lobe and 42% cases from lower lobe. Site of haemoptysis for 19 patients was from left lung (38%) in which upper lobe, lingula and lower lobe were involved in 31.5%, 10.5,1 and 58% cases respectively.

The diameter of the bronchial arteries ranged between 1.3 to 2.7 mm, with a mean value of 2.1 mm. MDCT analysis revealed either a dilated bronchial artery or tortuous course or both as the source of haemoptysis in 36 cases. The probable sources of bleeding that caused haemoptysis among our patients are depicted by Table 4.

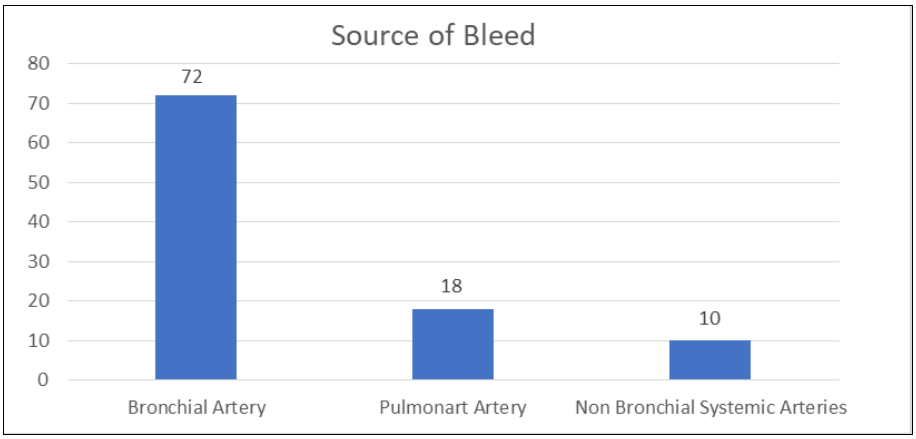

Fig 3: Source of bleeding in the lungs of study participants

The branching pattern of the bronchial arteries in the study is represented in Figure 4. With regard to the variations in bronchial artery origin, in 43 (86%) patients the origin was orthotropic i.e. T4-T5 vertebral level from the descending thoracic aorta, while 7 patients showed origin of bronchial artery from ectopic site, from the arch of aorta. A total of 145 bronchial arteries were detected by MDCT. There were 74 (51%) right bronchial arteries and 71 (49%) left bronchial arteries. Among those with left bronchial variants, a majority of patients possessed a single left bronchial artery (58%) whereas two left bronchial arteries were noticed in 42% cases.

Table 4: Branching pattern of bronchial arteries involved in haemoptysis

Branching patterns	Frequency	Percent
1 right ICBT + 1 left BA	7	14.0
1 right ICBT + 2 left BA	7	14.0
2 right BA (1 ICBT) + 1 left BA	1	2.0
1 right BA + 2 left BA	9	18.0
1 right BA + 1 left BA	2	4.0
2 right BA + 1 left BA	16	32.0
2 right BA + 2 left BA	5	10.0
3 right BA + 1 left BA	1	2.0
1 right CBT + 1 left BA	2	4.0
Total	145	100.0

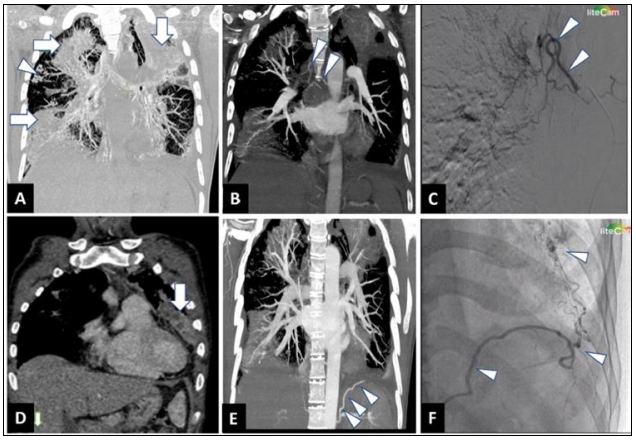

Fig 4: A 35 year old male patient with complaints of recurrent episodes of massive haemoptysis. [A] Coronal MIP image showing consolidations in both lungs (arrows) & tree in bud opacities (arrow head). [B] - Angiography image showing prominent right bronchial artery (arrow) from the proximal descending thoracic aorta (arrow head). [C]- Selective arteriogram showing a hypertrophied and tortuous right bronchial artery (arrow head). [D] Coronal contrast images showing a cluster of cystic spaces in the lingular segment of left lung (arrow). [E] Angiography image showing tortuous left phrenic artery (arrow heads). Arising from the abdominal aorta. [F] Selective arteriogram of hypertrophied and tortuous left phrenic artery (arrow heads).

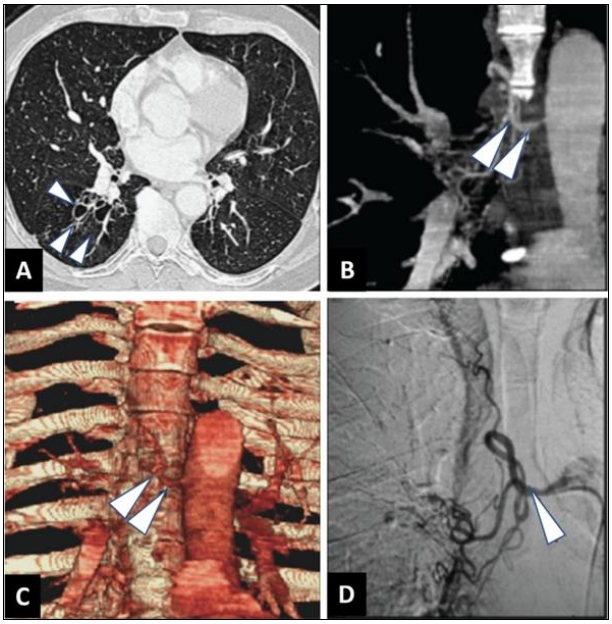

Fig 5: A 77 year old male patient presented with complaints of Cough with expectoration and haemoptysis

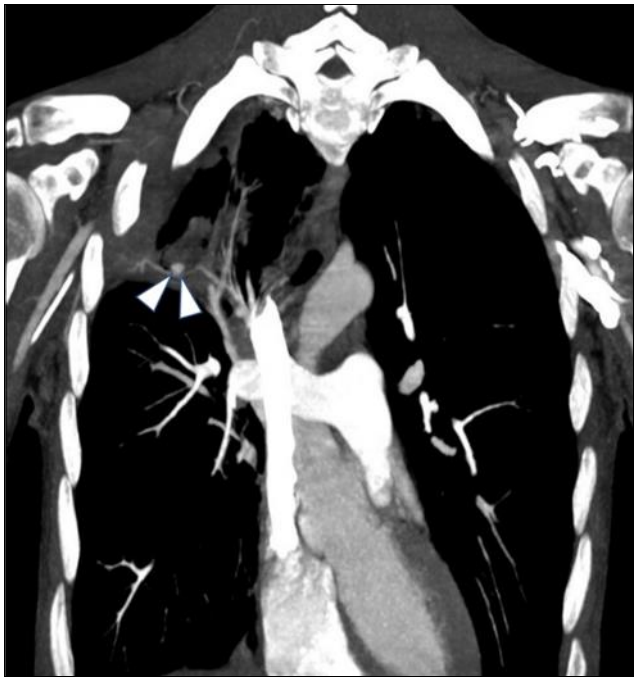

Fig 6: A 62 year old male patient with past history of Tuberculosis and a known diabetic and hypertensive with haemoptysis. CT angiogram oblique maximum intensity projection (MIP) image of the right pulmonary artery reveals a small aneurysm (arrow heads) arising from an upper lobe segmental artery

Discussion

Haemoptysis is a potentially serious and life-threatening symptom that serves as an indicator of myriad fatal diseases [1]. Routine pulmonary diagnostic tests provide limited information on disease pattern manifestation can be extracted from these diagnostic tests [11]. Detailed knowledge of the cause, severity, bleeding site and mechanism of haemoptysis is essential for planning appropriate treatment [12]. The current study has been aimed to evaluate the role of MDCT in the management of haemoptysis in a tertiary care teaching hospital. The study has included 50 patients experiencing haemoptysis. Evaluation of study cohort was carried out using MDCT angiography images to localize the site and source of bleed.

Etiological factors of haemoptysis are multifarious in nature and can be broadly classified into lung diseases, cardiovascular diseases, vasculitis, coagulopathy, cancer, iatrogenesis, and drug use [13].

A study by Bhalla *et al.* reported tuberculosis to be responsible for haemoptysis in 65% of patients, with bronchiectasis, pneumonia and malignancy being the other etiologies [14]. Other antecedent studies have also described similar findings [15, 16]. In this study as well, tuberculosis remains the primary causative factor of haemoptysis, identified in 46% of the patients followed by bronchiectasis (20%). The slight difference in prevalence rates may be due to the variation in sample size and epidemiological profile of local populace.

Khalil *et al.* conducted a study which reported ability of 16-MDCT scan in tracing bronchial arteries and its role in haemoptysis.[2]Similarly studies, on comparing MDCT and angiography results in patients with haemoptysis, found that MDCT provided a more precise depiction of bronchial arteries than conventional angiography did [17, 18]. They also found that 3D images are relatively more accurate than transverse CT images for visualizing bronchial arteries with ectopic origins [18].

Sherif A.A. Mohamed *et al*. have found that bronchial arteries were the most common source for massive haemoptysis as a consequence of high pressure, and 10% - 30% of cases are due to non-bronchial systemic circulation [3]. The result of the current study is in concordance with the above-mentioned study. Out of 50 patients, 36 patients (72%) showed bronchial artery and 5 patients (10%) showed non bronchial systemic arteries as the source of haemoptysis. Normally, the BA a small yet important vessel stems from the descending thoracic aorta and supplies high pressure oxygenated blood to the lung airway, esophagus, and lymph nodes [19-21].

The Bronchial artery has a diameter of 2 mm at their origin and 0.5 mm distally on entering the Broncho pulmonary segment [22]. Yoon *et al.* retrospectively compared MDCT images in patients with haemoptysis who underwent BAE, and, the diameter of bronchial arteries in MDCT, which were abnormal on angiography, were in range of 1.3-4.7 mm (mean, 2.8 mm) diameter [17]. In the present study, cut off of 2 mm was taken as a diameter of abnormal bronchial arteries. Conventional angiography was performed after MDCT study in 5 (10%) patients, who underwent embolization. Among whom, abnormal bronchial arteries were identified in 4 patients and an abnormal NBSA was seen in one patient. Upon comparing the findings, all the BAs were prospectively confirmed as abnormal in MDCT.

Antoine Khalil *et al*. described ground glass opacities or alveolar condensation as the two major signs of haemoptysis in the lung parenchyma, which rarely presents as atelectasis caused by clots obstructing the bronchi, contrast extravasations [2]. In regard to the bleeding site localization, the current study reveals abnormal CT findings in the form of focal parenchymal abnormality or opacity (either ground glass opacity or consolidation) independent of gravity. The presence of alveolar filling, cavitations and/or a mass were considered to be localizing lesions.

MDCT angiography has a great value in depicting the origin of the bronchial arteries. In the present study 43/50 (86%) patients showed orthotopic origin of bronchial arteries, while 7/50 (11%) were ectopic. These findings are in

accordance with the literature where Abdel-Ghany *et al.* found that 90% of the bronchial arteries detected were orthotopic, and 10% were ectopic [23]. Sancho*et al.* also reported a majority of bronchial arteries to be of an orthotopic origin, with 8.3% bronchial arteries of ectopic origin.[24]However, studies by Mori et al. and Battal *et al.* have reported higher incidence of ectopic bronchial arteries to be 21.6 and 26.4% respectively [25, 26].

Cauldwell *et al*. classified the bronchial artery branching pattern into 4 groups: group 1- 1 right ICBT, 2 left bronchial arteries (40.6%); group 2- 1 right ICBT, 1 left bronchial artery (21%); group 3- 2 right (1 ICBT) and 2 left bronchial arteries (20%); and group 4 - 2 right (1 ICBT) and 1 left bronchial artery (9.7%) [27]. In our current study population, in terms of bronchial artery variants we observed the combination of 1 right ICBT and 1 left bronchial artery classified as group 2 by Cauldwell *et al*. in 17.14% of patients [27]. Similarly, another 17.14% of study cohort had group 1 type (1 right ICBT, 2 left bronchial artery) branching pattern. However, the most common branching pattern observed in this study was 2 right bronchial arteries and 1 left bronchial arteries (25.71%), which though not a part of the Cauldwell *et al.* classification, and not 1 right ICBT and 1 left bronchial artery as reported by previous studies [27-30].

The present study found that the right bronchial arteries were higher in number (51%) when compared to the left bronchial arteries (49%). This may be a result of the increased right lung volume and the large amount of blood that the right bronchial arteries carry to feed structures, such as trachea, the extra- and intrapulmonary airways, supporting tissues, lymph nodes, and visceral pleura. The study data showed that the vascular source of haemoptysis and most probable site of the bleed were detectable with MDCT angiography. It was also helpful in identifying normal variants of bronchial artery and anatomy of the non-bronchial systemic arteries. The novelty of this research lies in its effort to map out the several branching patterns of arteries associated with haemoptysis beyond what is known from existing literature.

The major limitation of this study was the selective conventional angiography and bronchoscopy performed in a limited number of patients. Hence exact source of bleed was not confirmed in all patients. A small sample size limits the study's scope in assessing the prevalence rates of haemoptysis, which have not been adequately documented in existing literature. Future research can delve into multicentric analysis of MDCT as a diagnostic tool for haemoptysis, prevalence of haemoptysis and factors that bring abnormal origin, branching and course of flow.

Conclusion

MDCT angiography facilitates swift, detailed and accurate evaluation of the root cause and consequences of haemoptysis.[28] The study showcases the potential of MDCT in identifying the cause, probable site of bleed and the anatomical course of bleeding vessels supplying the abnormal lung parenchyma. By doing so, it provides a precise road map to guide for further therapeutic embolization procedures.

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