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Original research article

Multi-detector computed tomographic pulmonary angiography in the evaluation of acute pulmonary thromboembolism

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Abstract

Background: Pulmonary embolism (PE) is a common condition with remarkable morbidity and mortality. The rapid and accurate diagnosis is important because the mortality of untreated PE is high and complications can occur with long-term anticoagulant treatment. As signs or symptoms are not specific for this condition, the diagnosis is largely based on imaging tests. Since the introduction of Multi-detector computed tomography (MDCT) technology with high spatial and temporal resolution MDCT-Pulmonary Angiography (MDCTPA) has become the imaging method of choice for imaging lung vessels when PE is suspected.

Materials and Methods: This study is a prospective study carried out on 63 patients who underwent computed tomographic pulmonary angiography over a period of 12 months duration at The Oxford Medical College, Hospital & Research centre, Bengaluru from January 2022 to December 2022. They were 39 males and 24 females and their ages ranged from 18 to 84 years (mean 50.15 years). CTPA were interpreted to assess the presence of thrombus and other significant findings. The vascular obstruction index was quantified using the Qanadli scoring index and CT signs were used to assess right ventricular dysfunction (RVD). The findings of the CTPA were compared with 2D-echo features of RVD among others. Also, all the 63 patients were evaluated for any incidental vascular findings.

Results: CTPA reported that 24 (38%) of them were positive for pulmonary embolus while remaining 39 (62%) were negative for pulmonary embolus. The mean age of all the patients was 50.15 ± 16.9 years & male to female ratio was found to be 1.63:1. Of total 63 patients on whom the CTPA was performed, 39 (62%) showed no signs of occlusion and hence graded as score 0, while 24 (38%) showed partial occlusion graded as score 1. Based on the quantification of obstruction using Qanadli scoring index a cut off value of 40% was taken and was analysed. Thus, a total of 24 PE positive patients were divided into two groups; one group of PAOI ≤ 40% (n=8, 33.3%) and other group of PAOI between 41-100% (n=16, 66.7%). D-dimer assay was positive in 35 patients and negative in remaining 28 patients of suspected PE. ECG findings like sinus tachycardia and right bundle branch block are higher in PAOI > 40-100% group (87.5% and 25% respectively) as compared to PAOI≤ 40% group (50% and 12.5% respectively). In PAOI > 40-100% group, the proportion of cases with RVd/LVd> 1, Pad/AOd> 1 and PTd> 29 mm was found to be 93.8%, 81.3% and 75% respectively.

Conclusion: Risk stratification of patients with PE is important because optimal management, monitoring and therapeutic strategies depend on the prognosis. Accordingly, pulmonary artery obstruction index (PAOI) based on Qanadli score could be used to grade the severity of pulmonary embolism and to monitor patients requiring an objective repetitive evaluation. However, further evaluations are needed to investigate the usefulness of the PAOI for determining stratification of patient risk and influencing therapeutic decisions. With greater education of clinicians in this radiological scoring, a rapid assessment for diagnosis, clinical risk evaluation, and prognosis may be possible in the emergency services.

Keywords: Computed tomographic, pulmonary angiography, acute pulmonary thromboembolism

Introduction

Pulmonary embolism is the partial or complete occlusion of one or more central or peripheral pulmonary arteries by thrombi [1]. Because of their non-specific clinical presentation, PE is often referred to as the "great masquerader" and remains a diagnostic challenge for clinicians and radiologists [2]. There is a continuous rise in the incidence of pulmonary embolism as a result of the increase in the various pre-disposing factors [3, 4].

The global incidence of acute venous thromboembolism (VTE) ranges between 23-69/100,000

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population/year. PE is the third most common cause of cardiovascular mortality after ischemic heart diseases and stroke in developed Western countries. Untreated PE is fatal in up to 30% of patients, but the mortality rate is 2-10% even with timely diagnosis and treatment. Therefore it is very important to diagnose PE quickly and accurately. The nonspecific clinical signs and symptoms of PE make the diagnosis even more difficult. Diagnostic algorithms are needed to assist clinical assessment and optimize the use of diagnostic tests especially in an emergency setting [5, 6].

Diagnostic algorithms and guidelines based on clinical probability combined with D-dimer-test and various imaging methods {echocardiography, compression ultrasonography of the deep veins of the lower limbs, invasive catheter pulmonary angiography, ventilation-perfusion scintigraphy, CT pulmonary angiography (CTPA) and MR angiography (MRA) support the correct diagnosis [7].

The approach to PE has changed considerably after the introduction of multi-detector computed tomographic pulmonary angiography (CTPA). CTPA is the diagnostic method of choice widely used currently due to its convenience, speed, sensitivity and its ability in visualizing clots and excluding alternate diagnoses [8].

The most amazing advantage of MDCT technology is quick data acquisition and the 3D reconstruction protocol that allows for different testing. Short scanning reduces artifacts by heart and respiratory movement, facilitating visualization of adjacent heart vessels. Pulmonary embolism results in a rapid increase in pulmonary vascular resistance that may lead to right ventricular dysfunction (RVD) eventually causing heart failure and death. Patients with PE with RVD have a higher mortality rate than those without RVD, even if they are clinically stable initially [9], hence rapid risk assessment is essential in selecting the appropriate treatment strategy in these patients who may benefit from thrombolysis or embolectomy in addition to anticoagulation. Since CTPA includes the assessment of the heart and all its chambers, its prognostic value is enhanced by evaluation of the right ventricle [10].

Fine collimation improves the representation of sub-segmental arteries and hence helps in the diagnosis of PE with high diagnostic confidence. Faster scans require less intravenous contrast, a benefit for patients with heart failure and renal factor [11].

Significant incidental vascular findings can also be detected on CTPA in patients with suspected pulmonary embolism like calcification of the aorta and coronary arteries, dilatation of the pulmonary trunk and thoracic aortic aneurysms among others that may warrant recognition as they may even provide an alternate diagnosis [12].

The major studies found sensitivity and specificity of CTPA between 80 and 100%. The predictive value of CTPA significantly depends on the clinical probability of PE. The specificity and positive prognostic value of CTPA is also influenced by the position of emboli in the pulmonary arterial tree. The clinical relevance and necessity of treatment of isolated, sub-segmental emboli is highly controversial as anticoagulation therapy can increase mortality due to bleeding complications. CTPA has been recognized as the standard gold standard for a large multi-center PE study (PIOPED) [13].

CTPA has established itself as the first imaging test because of its high negative predictive value for PE with high clinical probability or elevated D-dimer level. Hence CTPA is recommended in all patients with high clinical suspicion of PE except for some special clinical situations (pregnancy, known adverse reaction to contrast material and renal failure).

CTPA has completely replaced invasive catheter pulmonary angiography and ventilation-perfusion scintigraphy as first line imaging tool in diagnosis of PE [14].

Materials and Methods

This study is a prospective observational study carried out on patients who undergo CTPA. All patients who underwent CTPA in the department of Radio-diagnosis, The Oxford Medical College, Hospital & Research centre, Bengaluru from January 2022 to December 2022.

Inclusion criteria

1. All patients undergoing CT pulmonary angiography for suspected acute pulmonary thromboembolism.

Exclusion criteria

1. Patients diagnosed to have pulmonary embolism earlier who are on follow up.
2. Sub-optimal studies due to patient motion or other artifacts.

Sample size

A sample size of at least 34 subjects was obtained by using the hypothesis testing method and based on following assumptions: 95% confidence intervals, prevalence of pulmonary embolism with CTPA in study [10] done in Egypt in 35 patients out of total 70 suspected pulmonary embolism, correlation between obstructive index and the CT pulmonary artery diameter 0.66, 80% power, population correlation 0.86 and 10% margin of error.

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Statistical analysis
Data was cleaned, Validated and Analyzed by IBM SPSS version 20.0.

Descriptive statistics
- For continuous variable range, mean and standard deviation were calculated and for categorical variables proportion and percentage were obtained.

Bi-Variate analysis
- To know the association between dependent and independent variable chi-square and correlation test applied accordingly.

Data collection method
- The study was presented to Institutional Ethics Committee (IEC) for ethical clearance, after getting clearance form IEC the study was started.
- All selected subjects were approached and personally met & briefed about the study.
- After taking informed consent, a detailed questionnaire was administered to the selected patients, according to their convenience. Strict confidentiality was employed in carrying out the survey and use of information provided by each respondent.

All the patients included in the study underwent CTPA according to the institution protocol using a 32-slice CT scanner (GE Revolution Act). The scan range extends from the base to the apex of the lungs in the caudal to cranial direction done during a single respiratory breath-hold. Optimal amount of non-ionic contrast medium Iopromide (Ultravist 300mg I/ml, Bayer Healthcare) was injected through an arm vein with an 18-20 gauge intravenous cannula by using an automated power injector at the rate of 4ml/s, followed by a saline chase of 30 ml. Arterial phase scanning was initiated by bolus tracking when a threshold enhancement of 85-90 HU was reached in the main pulmonary artery. The venous phase acquisition delay was 25 seconds after the injection of contrast.
Source and reformatted images were used to calculate CT vascular obstruction index, the right and left ventricular diameters, pulmonary arterial and ascending aortic diameters, interventricular septal morphology, identification of reflux of contrast medium in the inferior vena cava or hepatic veins and any other significant findings.

Results

Table 1: CTPA findings in suspected pulmonary embolism patients (N=63)

CTPA findings	Number of patients
Pulmonary embolus present	24 (38.0%)
Pulmonary embolus absent	39 (62.0%)
Total	63 (100%)

Table 2: Age wise distribution of study participants undergoing CTPA (N=63)

Age (in years)	Pulmonary Embolism on CTPA		Total	*p*-value*
	Negative	Positive		
<30	6 (15.3%)	6 (25.0%)	12 (19.1%)	
30-39	4 (10.3%)	1 (04.2%)	5 (7.9%)	
40-49	4 (10.3%)	6 (25.0%)	10 (15.9%)	
50-59	8 (20.5%)	6 (25.0%)	14 (22.2%)	
≥ 60	17 (43.6%)	5 (20.8%)	22 (34.9%)	
Total	39 (100%)	24 (100%)	63 (100%)	
Mean age ± SD	52.7 ± 18.3	45.9 ± 13.6	50.15 ± 16.9	0.12
* *p*-value is based on unpaired t-test				

Table 3: Sex wise distribution of study participants undergoing CTPA (N=63)

Sex	Pulmonary Embolism on CTPA		Total	*p*-value*
	Negative	Positive		
Male	23 (59.0%)	16 (66.6%)	39 (61.9%)	0.54
Female	16 (41.0%)	8 (33.4%)	24 (38.1%)	
Total	39 (100%)	24 (100%)	63 (100%)	
Male: Female	1.43 : 1	2 : 1	1.63 : 1	
* *p*-value is based on chi-square test				

Table 4: Degree and site of pulmonary obstruction as detected on CTPA on suspected pulmonary embolism patients (N=63)

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Parameter	CTPA findings (N=63)
Degree of obstruction	
0 = No thrombus	39 (62.0%)
1 = Partial occlusion	24 (38.0%)
2 = Total occlusion	0 (0%)
Site of obstruction (score denotes number of segmental arteries)	
0	39 (62.0%)
1 - 5	4 (6.3%)
6 - 10	1 (1.6%)
11 - 20	19 (30.1%)
0 score on thrombus and 0 involvement of segmental arteries denotes that pulmonary embolism is absent on CTPA	

Table 5: Pulmonary Artery Obstruction Index (Qanadli Score) as detected by CTPA (N=24)

Qanadli Score (0 - 40) ≈ PAOI (0%-100%)	Number of patients
≤ 16≈ ≤ 40%	8 (33.3%)
17- 40≈ 41 - 100%	16 (66.7%)
Total	24 (100%)
Mean ± SD QS = 15.5 ± 6.9 Mean ± SD PAOI = 38.8% ± 17.3%	

Table 6: 2-D echocardiography findings and its association with Pulmonary Artery Obstruction Index (PAOI) (N=24)

2-D Echo findings	PAOI		*p*-value*
	≤ 40%	>40 – 100%	
RAd (> 5.3 cm)	4 (50.0%)	11 (68.8%)	0.65
RVd (> 4.2 cm)	4(50.0%)	11 (68.8%)	0.65
PASP (> 34 mmHg)	4(50.0%)	13 (81.3%)	0.26
TAPSE (< 16 mm)	4(50.0%)	12 (75.0%)	0.44
Total	8 (100.0)	16 (100.0)	
* *p*-value is based on chi-square test. % in round brackets are calculated out of total PAOI≤ 40% and PAOI > 40-100% respectively. RAd = right atrial diameter; RVd= right ventricular diameter; PASP = pulmonary artery systolic pressure; TAPSE = tricuspid annular plane systolic excursion			

Discussion

All 63 patients of suspected PE were subjected to CTPA. CTPA reported that 24 (38%) of them were positive for pulmonary embolus while remaining 39 (62%) were negative for pulmonary embolus.

In a study conducted by Nduta [7], 27% were found to have evidence of pulmonary embolus on multi-detector computed pulmonary angiography. Burkill GJ *et al.* [8] showed that CTPA was positive for pulmonary embolism in 28 out of 101 patients (28%). In a similar study done by Attia NM *et al.* [9], among 70 patients with suspected PE, 35 patients (50%) were found to be positive for PE in CTPA. Qanadli SD *et al.* [10] performed CTPA on 158 patients, among which 54 (34%) were proven to have pulmonary embolism. The prevalence rate of pulmonary embolism in our study is comparable toother published studies [11] which have reported approximately 35% prevalence of PE inclinically suspected cases.

The mean age of suspected PE cases was 52.6 years in a study done by Nduta [7]. The same study reported that 50% of PE positive cases were more than 60 years, which is contrasting to our findings; however, there was no statistically significant difference between the mean age of PE positive and PE negative cases, which is similar to our study. In study by Rodrigues B *et al.* [12], the mean age of PE positive cases was 61 years. Ahmad DS *et al.* [13] reported a mean age of 53 years in his study. A similar study by Kang DK *et al.* [14] showed the mean age of acute PE cases was 55 years. Hefeda MM *et al.* [15] reported mean age of PE positive cases to be 57 years, while Enes EG *et al.* [17] reported mean age of 62 years in PE positive cases.

In our study shows the sex wise distribution of PE positive and PE negative cases. Out of total 63 suspected PE cases in our study, majority were males (62%). The male to female ratio was found to be 1.63:1. The proportion of PE negative cases were higher in males (59%) as compared to females (41%). Also, in PE positive cases, the proportion of males (66.6%) was higher than females (33.4%). The male to female ratio in PE negative and PE positive patients was found to be 1.43:1 and 2:1 respectively. However, the two groups did not differ statistically significantly with respect to their sex.

Contrast to our study findings, the male to female ratio in PE positive and PE negative patients in a study conducted by Nduta[7] was 1:2 and 1:2.1; however, the difference in both the groups with regards to sex was found to be statistically non-significant. In the same study, females represented the majority (67%) of all suspected PE cases, which is contrast to our findings. Predominance of females in PE positive cases was also reported in a studies done by Rodrigues B *et al.* [8] (63%), Ahmad DS *et al.* [13] (57%), Enes EG *et al.* [17] (62%) and Selimoglu Sen H *et al.* [18] (60%). A study done by Kang DK *et al.* [14]

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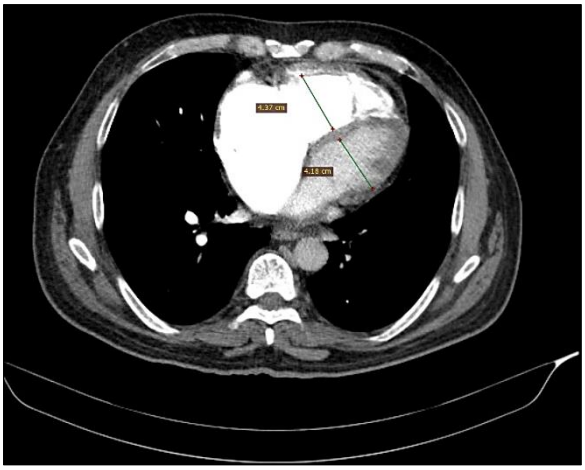
showed majority of PE positive cases were males (53%). Similar observation was made in study by Hefeda MM *et al*. [15] where 65% of PE positive cases were males. The proportion of males and females in PE positive cases was almost similar in a study conducted by Attia NM *et al*. [9].

The degree and site of pulmonary obstruction as detected by CTPA on suspected pulmonary embolism patients. Of total 63 patients on whom the CTPA was performed, 39 (62%) showed no signs of occlusion and hence graded as score 0, while 24 (38%) showed partial occlusion graded as score 1. Total occlusion (graded as score 2) was not seen in any of the patient. Based on the number of segmental arteries involved, 39 (62%) scored 0, 4 (6.3%) scored between 1-5, 1 (1.6%) scored between 6-10 and majority i.e. 19 (30.1%) scored between 11-20. Zero score on thrombus and no involvement of segmental arteries denotes that pulmonary embolism is absent on CTPA.

The use of Qanadli score (QS) to determine the pulmonary artery obstruction index (PAOI). An optimal cut off-value of 16 for Qanadli score which is equivalent to 40% of PAOI was established after constructing an ROC curve. The sensitivity and specificity values were 78% and 84% respectively. Thus a total of 24 PE positive patients were divided into two groups; one group of PAOI ≤ 40% (n=8, 33.3%) and other group of PAOI between 41-100% (n=16, 66.7%).

Representative cases



52 year old male patient (subject no. 9) with PE, showing measurement of ratio right ventricle and left ventricle. It was greater than unity.

52 year old male patient (subject no.9) with PE, showing measurement of Pulmonary artery and Aortic diameter and their ratio. It was greater than unity.

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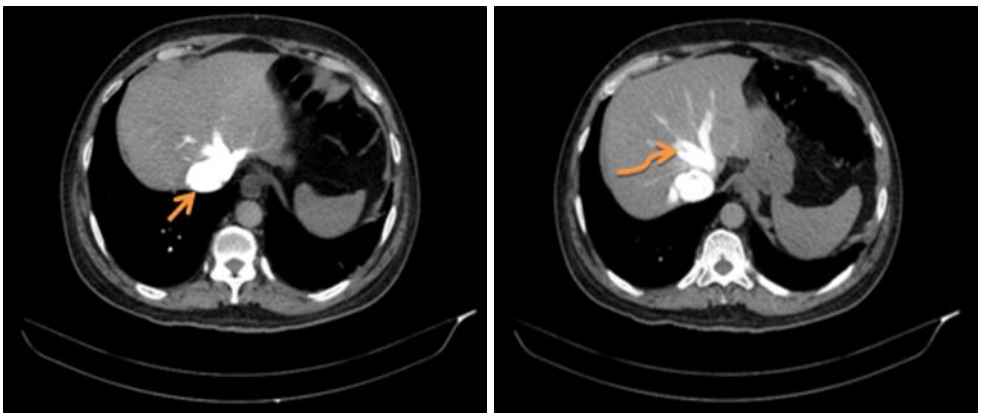
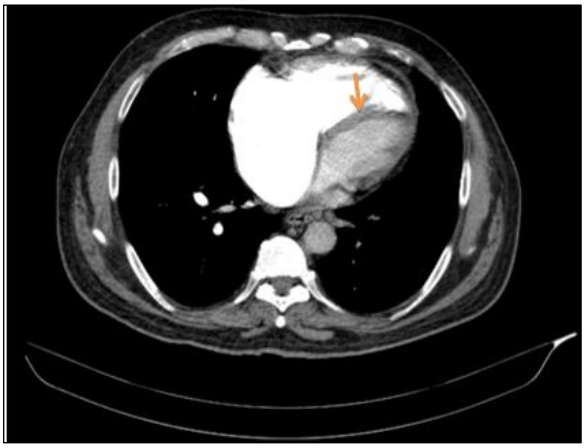
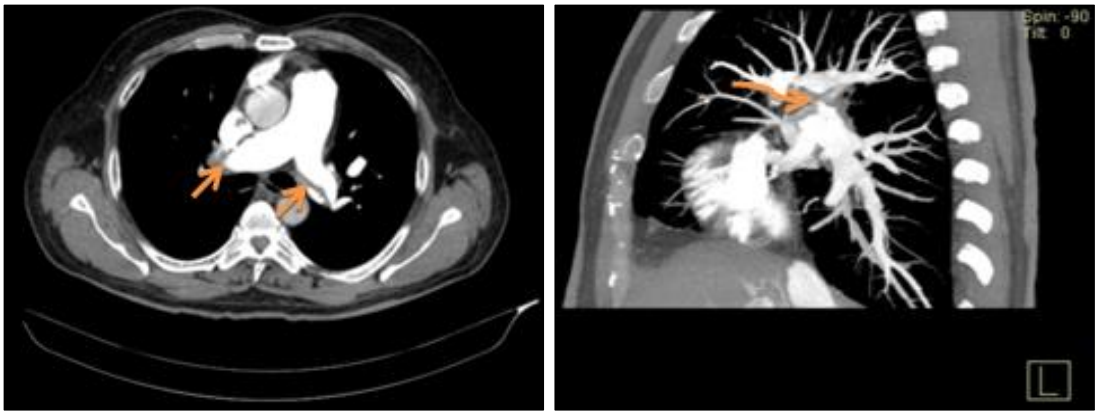


52 year old male patient (subject no.9) with PE, showing reflux of contrast in to the IVC (straight arrow) and up to the midpoint of hepatic veins (curved arrow)



52 year old male patient (subject no. 9) with PE, showing bowing of IVS towards the left side.



52 year old male patient (subject no. 9) with PE, showing partial obstruction of both the right and left pulmonary arteries (straight arrows) and curved arrow in the MIP image shows partial obstruction of the right main pulmonary artery. Calculated PAOI was 50%.

Conclusion

In this study, CTPA also offered the advantage of delineating other vascular findings besides PE that might explain the patient's presentation. These may require further investigations.

Presence or absence of pulmonary embolus was not significantly associated with other positive chest X-ray findings. However, it was significantly associated with deep vein thrombosis. Hence, it is advisable to concomitantly evaluate the patient with venous Doppler for lower limb.

To conclude, risk stratification of patients with PE is important because optimal management, monitoring, and therapeutic strategies depend on the prognosis. Accordingly, pulmonary artery obstruction index (PAOI) based on Qanadli score could be used to grade the severity of pulmonary embolism and to monitor patients requiring an objective repetitive evaluation. However, further

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evaluations are needed to investigate the usefulness of the PAOI for determining stratification of patient risk and influencing therapeutic decisions. With greater education of clinicians in this radiological scoring, rapid assessment for diagnosis, clinical risk evaluation, and prognosis may be possible in the emergency services.

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