World Journal of Current Medical and Pharmaceutical Research
Content available at www.saap.org.in ISSN: 2582-0222

MULTI-DETECTOR COMPUTED TOMOGRAPHIC PULMONARY ANGIOGRAPHY IN THE EVALUATION OF ACUTE PULMONARY EMBOLISM

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DOI: https://doi.org/10.37022/wjcmpr.v8i3.430

ARTICLE HISTORY
Received on: 14-07-2026
Revised on: 24-08-2026
Accepted on: 19-09-2026

Keywords: *Multi-detector Computed Tomography (MDCT), Pulmonary embolism, Pulmonary artery obstruction index, Qanadliscore, CT signs of right ventricular dysfunction, D-dimer.*

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ABSTRACT

Background: Pulmonary embolism (PE) is a potentially life-threatening condition associated with significant morbidity and mortality. Since its clinical presentation is often nonspecific, CT pulmonary angiography (CTPA) plays a key role in diagnosis and assessment of disease severity.
Aim: To estimate the prevalence of acute PE in patients with acute chest symptoms and high clinical suspicion, assess pulmonary arterial obstruction using the Qanadli scoring index, evaluate CT markers of right ventricular dysfunction, and compare CTPA findings with plasma D-dimer levels.
Methods: A cross-sectional study was conducted among 100 clinically suspected PE patients referred to the Department of Radiodiagnosis, Government Medical College, Thrissur, during 2021–2022. CTPA was performed to identify pulmonary arterial thrombi and associated findings. Pulmonary artery obstruction was quantified using the Qanadli score, and CT parameters were assessed for right ventricular dysfunction. Data were analyzed using IBM SPSS version 25.0.
Results: PE was detected in 33% of participants. The majority were aged ≥60 years (54%), with an equal male-to-female ratio. Among PE-positive patients, 60.6% had a pulmonary artery obstruction index (PAOI) ≤33%, while 39.3% had PAOI >33%. D-dimer was positive in 87.9% of PE patients. Deep venous thrombosis and post-COVID infection were reported in 69.6% and 57.5%, respectively. Cough and dyspnea were the most common symptoms. In patients with PAOI >33%, RV/LV ratio >1, PA/Ao ratio >1, and pulmonary trunk diameter >29 mm were each observed in 86.6%. The right lower lobe (75.7%) and segmental arteries (42.4%) were most frequently involved.
Conclusion: CTPA effectively detects PE and provides important information regarding the site and severity of pulmonary arterial obstruction. The Qanadli score may be useful for severity assessment and risk stratification, while CT markers can aid in identifying right ventricular dysfunction.

INTRODUCTION

Pulmonary embolism is the partial or complete occlusion of one or more central or peripheral pulmonary arteries by thrombi [1]. It is the third most common acute cardiovascular disease after myocardial infarction and stroke and results in thousands of deaths each year. Due to the nonspecific clinical presentation, PE is often referred to as the 'great masquerader' and therefore it remains a diagnostic challenge for clinicians and radiologists [2]. The global incidence of acute venous thrombo-embolism ranges between 23-69/100000 population/year. Untreated PE has a significant fatality rate of up to 30% of patients, however early identification and treatment still result in a mortality rate of 2–10%. Prompt diagnostic algorithm is needed to assist clinical assessment and optimize the use of diagnostic tests especially in an emergency setting [3,4]. The diagnostic evaluation of a patient with suspected PTE usually begins with the analysis of the pre-test probability and the standard D-dimer values. Such evaluations typically based on the two most validated clinical scoring systems- the Wells score and the Geneva score. Diagnostic algorithms and guidelines based on clinical probability combined with D-dimer test and various imaging methods (echocardiography, ultrasonography of deep veins of the lower limb, invasive pulmonary angiography, ventilation perfusion scintigraphy, CTPA and Magnetic resonance

pulmonary angiography) support the correct diagnosis [5]. CTPA is the imaging modality of choice and has high sensitivity and specificity. It is readily available, minimally invasive and fast with scan duration in modern scanners of less than one second. Short scanning time reduces artifacts by cardiac and respiratory movements. The field of view of CTPA is not only limited to the pulmonary arteries but can reveal other etiologies of chest pain and shortness of breath such as musculoskeletal injuries, pericardial abnormalities, pneumonia, vascular pathologies, and even coronary artery disease in some protocols [6]. Pulmonary embolism results in a rapid increase in pulmonary vascular resistance and can cause right ventricular dysfunction (RVD) and heart failure. Patients with PE with RVD have a high mortality rate than those without RVD, hence rapid risk assessment is very important in selecting the appropriate treatment strategy in these patients who may benefit from either thrombolysis or embolectomy in addition to the routine anticoagulation therapy. CTPA includes the assessment of the heart and all its chambers; its prognostic value is enhanced by evaluation of the right ventricle [7, 8]. CT provides several parameters for estimating the severity of PE and risk-stratification, such as right heart strain, clot burden and lung perfusion. Features of right heart strain include-increased right ventricle (RV)/left ventricular (LV) diameter ratio (>1 in axial plane, >0.9 in 4-chamber reconstruction), flattening of inter-ventricular septum and reflux of contrast material into the IVC and hepatic veins. RV/LV ratio >1.1 has been associated with increased risk of death within 30 days. Four-chamber RV/LV ratio >0.9, combined with high-sensitivity-cardiac-troponin-I was associated with poor clinical outcome [6]. Quantification of pulmonary artery obstruction index using the Qanadli scoring system of *Qanadli et al* [9], is an important parameter in assessing the severity of PE. To define the CT obstruction index, the arterial tree of each lung was regarded as having [10], segmental arteries (three to the upper lobes, two to the middle lobe and to the lingula, and five to the lower lobes). The presence of embolus in a segmental artery was scored as 1 point, and emboli in the most proximal arterial level were scored as a value equal to the number of segmental arteries arising distally. To provide additional information about the residual perfusion distal to the embolus, a weighting factor was assigned to each value, depending on the degree of vascular obstruction. This factor was equal to zero when no thrombus was observed; 1 when partially occlusive thrombus was observed and 2 with total occlusion. Thus, the maximal CT obstruction index was 40. Isolated sub segmental embolus was considered as a partially occluded segmental artery and was assigned a value of 1. The percentage of vascular obstruction was calculated by dividing the patient score by the maximal total score and by multiplying the result by 100. Therefore, the CT obstruction index can be expressed as: $\Sigma (n \cdot d) / 40 . 100$, where n is the value of the proximal thrombus in the pulmonary arterial tree equal to the number of segmental branches arising distally (minimum, 1; maximum, 20), and d is the degree of obstruction (minimum, 0; maximum, 2) [9]. The major studies found sensitivity and specificity of CTPA between 80 and 100 %. CTPA is considered gold standard for a large multi-center prospective investigation of pulmonary embolism diagnostic study [10]. CTPA has replaced V/Q scintigraphy and invasive pulmonary angiography as first line imaging tool in diagnosis of PE [11]. CTPA has established as the first imaging test because of its high negative predictive value for PE with high clinical probability or elevated D-dimer values. Hence CTPA is recommended in all patients with high clinical suspicion of PE except for some special situations that include pregnancy, known adverse reaction to contrast material and renal failure. This prospective study evaluates the role of CTPA in correlating pulmonary artery obstruction index using qanadli score, with RVD in patients with acute PE.

MATERIALS AND METHODS

STUDY SETTING
Department of Radiodiagnosis, Govt. Medical College, Thrissur, Kerala, India

STUDY DESIGN
Cross sectional study

STUDY PERIOD
One year from the date of obtaining ethical clearance.

STUDY POPULATION
Patients referred to Radiodiagnosis department of Government medical college, Thrissur with acute chest symptoms with or without risk factors and suspected to having acute pulmonary embolism.

STUDY SUBJECTS
Inclusion criteria

Patients aged 18 to 80 years undergoing pulmonary angiography for suspected acute pulmonary embolism.

Exclusion criteria

- Patients who are not willing to participate in study
- Patients diagnosed to have pulmonary embolism earlier who were on follow-up.
- Patients with history of allergy to intravenous contrast agents.
- Sub-optimal imaging study due to movement artifacts.

SAMPLE SIZE CALCULATION
Sample size (n) calculated by the formula
N = 4PQ/d2
Where
P = prevalence (from previous study) [8].
Q = 100-p
d= allowable error (5-20% of p)
p = 50% and q = 50%, d = 20% of p :10
hence, sample size will be 100

SAMPLING PROCEDURE
Data collected from patients referred to the Radiodiagnosis department for performing CT pulmonary angiography based on inclusion and exclusion criteria. A brief history taken, and informed consent obtained from patients regarding willingness to participate in the study. Socio demographic details were also recorded. All patients included in this study subjected to CTPA according to the institutional protocol using 16 slice Siemens MDCT scanner. Scanning done pre and post administration of contrast medium in all patients. Scan range extended from the base to the apex of the lungs in the caudal to cranial direction during a single breath- hold. Source images were

reformatted using maximum intensity projection. Source and reformatted images 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 and hepatic veins and other significant findings.

REFERENCE STANDARD

CTPA is the gold standard for diagnosing pulmonary embolism

STATISTICAL ANALYSIS

Collected data analysed using Statistical Package for Social Sciences (IBM SPSS) version 25.0. Sociodemographic variables and study variables were analysed as proportions or percentages for categorical variables (Descriptive statistics). To know the association between dependent and independent variable Chi square test and correlation test applied accordingly (Bivariate analysis). The p value <0.05 considered as statistically significant.

OBSERVATION AND RESULTS

This study was conducted in the department of Radiodiagnosis, Govt. medical college, Thrissur during 2021 to 2022 in 100 participants based on inclusion and exclusion criteria.

Table-3: Distribution of Pulmonary Embolism of study participants

Presence of Pulmonary Embolism	Frequency (n=100)	Percentage
Yes	33	33.0
No	67	67.0
Total		100%

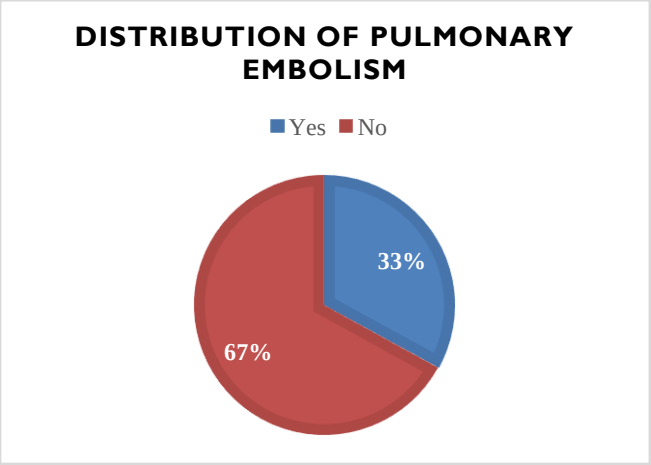

Figure 01: Pie diagram of Pulmonary Embolism

Table 04: Age distribution of study participants

Age	Frequency	Percentage
<30	3	3.0
30-39	8	8.0
40-49	13	13.0
50-59	22	22.0
≥ 60	54	54.0
Total	100	100.0

In our study, 3 (3.0%) participants were in the age group of below 30 years, 8 (8.0%) were in the age group of 30-39 years, 13 (13.0%) were in the age group of 40-49 years, 22 (22.0%) were in the age group of 50-59 years and 54 (54.0%) were in the age group of more than or equal to 60 years.

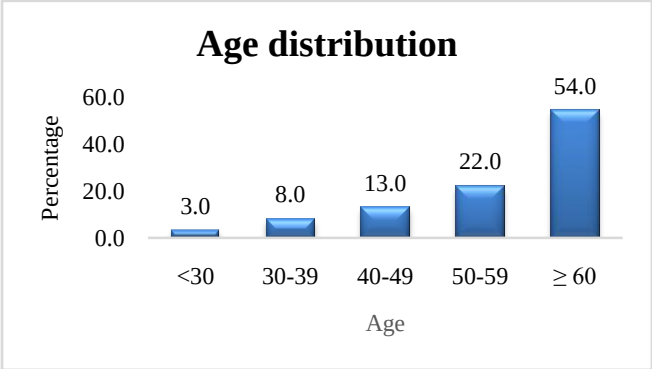

Figure 02: Simple bar diagram of Age

Table 05: Age wise distribution of study subjects undergoing CTPA

Age	Pulmonary Embolism				Total	χ^2 Value	p Value
	Present		Absent				
	n	%	n	%			
<30	0	0.0	3	4.5	3	14.418	0.006
30-39	1	3.0	7	10.4	8		
40-49	0	0.0	13	19.4	13		
50-59	12	36.4	10	14.9	22		
≥ 60	20	60.6	34	50.7	54		

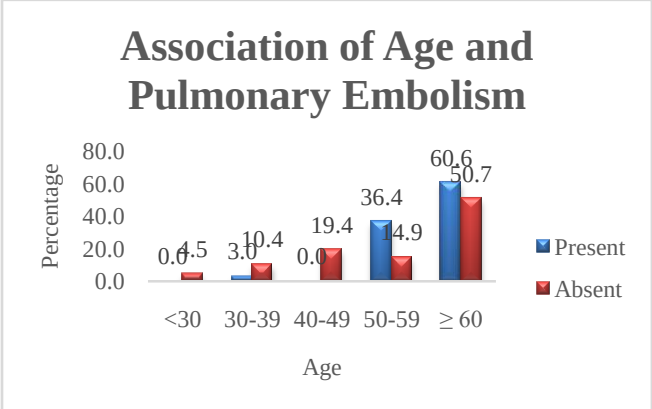

Figure 03: Age wise distribution of study subjects undergoing CTPA.

Table 06: Sex distribution of study participants

Sex	Frequency	Percentage
Male	50	50.0
Female	50	50.0
Total	100	100.0

In our study, 50 (50.0%) participants were male and 50 (50.0%) participants were female.

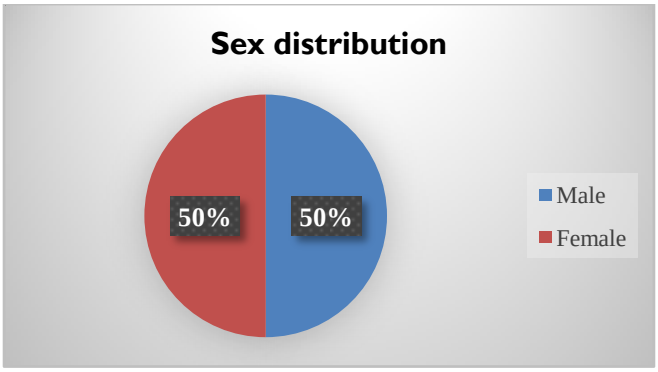

Figure 04: Pie diagram of sex distribution.

Table 07: Association between Sex and Pulmonary Embolism

Sex	Pulmonary Embolism				Total	χ^2 Value	p Value
	Present		Absent				
	n	%	n	%			
Male	26	78.8	24	35.8	50	16.327	<0.001
Female	7	21.2	43	64.2	50		

Pulmonary Embolism showed more in males 26 (78.8%) compared to females 7 (21.2%). The p-value revealed that gender was statistically significant with Pulmonary Embolism.

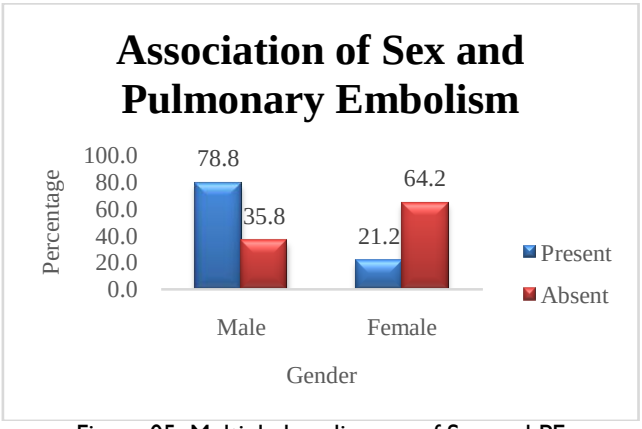

Figure 05: Multiple bar diagram of Sex and PE

Table 08: Degree and site of pulmonary obstruction as detected on CTPA in suspected pulmonary embolism patients. (N=100)

Parameter	CTPA findings (N=100)
Degree of obstruction	
0 = no thrombus	67%
1 = partial occlusion	30%
2 = total occlusion	3%
Site of obstruction (score denotes number of involved arteries)	
0	67 (67%)
1 – 5	10 (10%)
6 - 10	8 (8%)
11 -20	15 (15%)
0 score on thrombus and 0 involvement of segmental arteries denotes that pulmonary embolism is absent on CTPA.	

Table 09: Pulmonary artery obstruction index (quandli score) as detected by CTPA (N=33)

Quandli score (0-40) ≈ PAOI (0% -100%)	Number of patients
≤ 13 ≈ ≤ 33%	20 (60.6%)
14- 40 ≈ 34 – 100%	13(39.3%)
Total	33 (100%)

Table-10: Comparison of PAOI value with right ventricular dysfunction

RVD	N	PAOI			Mann-Whitney U Value	p Value
		Mean	SD	Median (IQR)		
> 1	19	44.47	15.27	45 (30-50)	8.00	<0.001
≤ 1	14	11.61	8.63	7.5 (5.0-16.25)		

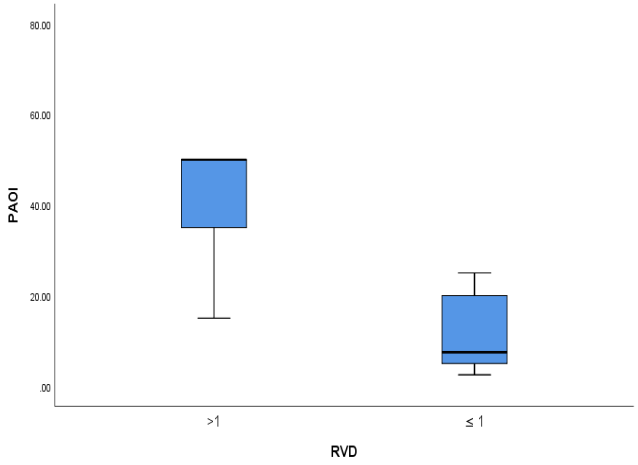

Fig 06: Box-plot for comparison of RVD and POAI

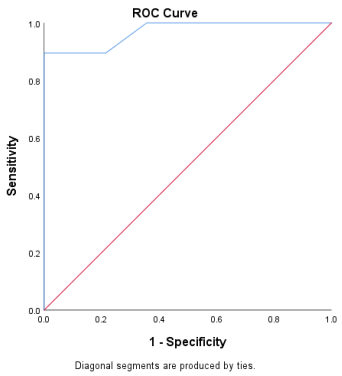

Figure 07: ROC curve for PAOI and Right Ventricular Dysfunction (RVD).

ROC curve was constructed to establish the cut off value for the POAI which was 33 with area under the curve of 0.970. Sensitivity was 78.9%, specificity was 100.0%, Positive Predictive Value was 100.0 and Negative Predictive Value was 77.8%.

Table 11: Association between D Dimer and Pulmonary Embolism

D Dimer Cut off :(0.5µg/ml)	Pulmonary Embolism				Total	χ^2 Value	p Value
	Present		Absent				
	n	%	n	%			
Positive/present	29	87.9	38	56.7	67	9.711	0.002

Negative/absent	4	12.1	29	43.3	33		

Pulmonary Embolism showed more in D-dmer participants 29 (87.9%) compared to normal 4 (12.1%). The p value revealed that D-dimer value was statistically associated with Pulmonary Embolism (p=0.002).

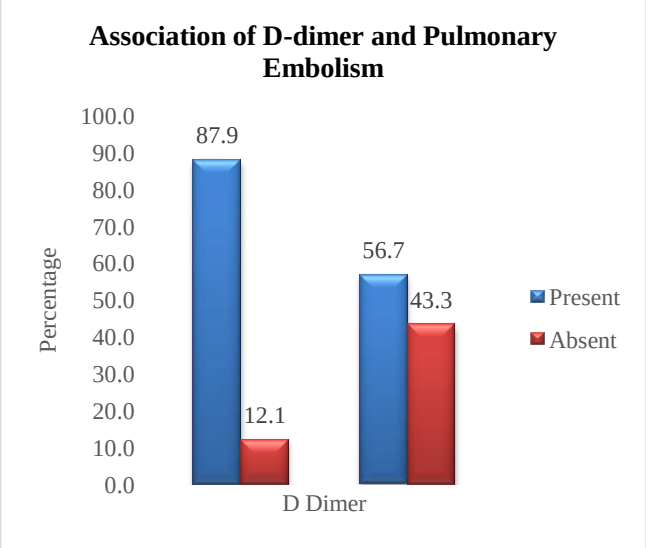

Figure 08: Multiple bar diagram of D-dimer and PE

Table 12: CTPA findings and their association with pulmonary artery obstruction index (N=33)

CTPA Findings	PAOI				p Value
	>33		≤ 33		
	n=15	%	n=18	%	
RvD/LvDd> 1	13	86.6%	4	22.2 %	0.00
PaD/AoD> 1	13	86.6 %	4	22.2 %	0.00
PtD> 29 mm	13	86.6 %	3	16.6 %	0.00
IVS bowing	8	53.3 %	0	0	0.00
IVC Reflux present	7	21.2 %	0	0	0.009

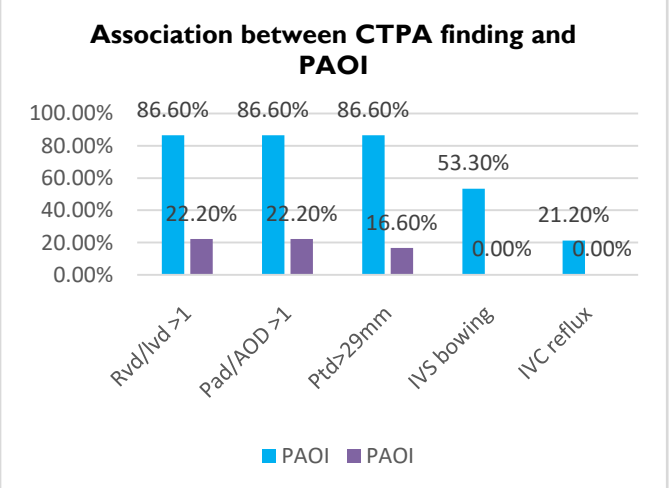

Figure 09: Bar diagram showing CTPA findings and their association with pulmonary artery obstruction index.

Table 13: Association of Clinical Findings with PAOI

Clinical Findings	PAOI				χ^2 Value	p Value
	>33		≤33			
	n=15	%	n=18	%		
Dyspnea	15	100.0	18	100.0	NA	NA
Cough	15	100.0	16	88.9	0.359	0.183
Chest Pain	11	73.3	13	72.2	0.005	0.943
Fever	5	33.3	4	22.2	0.103	0.748
Lower limb odema	3	20.0	8	44.4	2.200	0.138

Common clinical features in acute chest symptoms like dyspnoea, cough, chest pain, fever and lower limb oedema were analysed. None of the clinical findings were not statistically associated with PAOI.

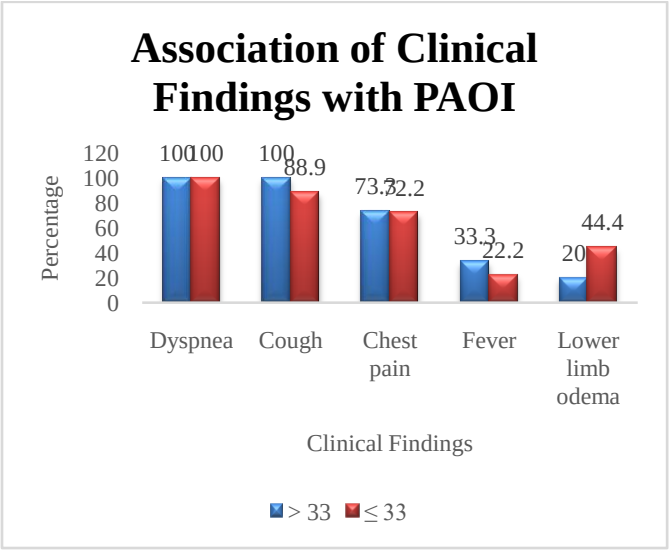

Fig 10: Percentage subdivided bar diagram of Clinical Findings and PAOI

Table-14: Association of Risk Factors with PAOI

Risk Factors	PAOI				χ^2 Value	p Value
	>33		≤34			
	n=15	%	n=18	%		
DVT	12	80.0	11	61.1	1.382	0.240
Recent trauma/surgery	7	46.7	4	22.2	2.200	0.138
Cancer	2	13.3	2	11.1	0.000	1.000
Diabetic Mellitus	6	40.0	8	44.4	0.000	1.000
Hypertension	8	53.3	9	50.0	0.000	1.000
Post Covid	8	53.3	11	61.1	0.009	0.923
Coronary Artery Disease	3	20.0	4	22.2	0.000	1.000

Considering the common risk factors in acute chest symptoms - DVT, recent trauma/surgery, cancer, diabetic

mellitus, hypertension, post covid and coronary artery disease were analysed. None of the risk factors were statistically associated with PAOI.

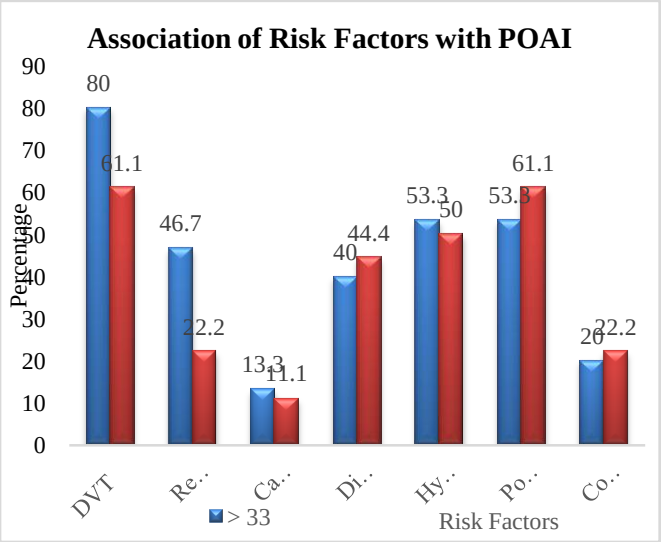

Figure 11: Percentage subdivided bar diagram of Risk Factors and PAOI

Table 15: Distribution of risk factors in pulmonary embolism positive patients

Risk factors	PE positive cases	Percentage
DVT	23	69.6%
Recent trauma/surgery	10	30.3%
cancer	4	12.1%
Diabetes mellitus	14	42.4%
Hypertension	17	51.5%
Post covid	19	57.5%
Coronary artery disease	7	21.2%

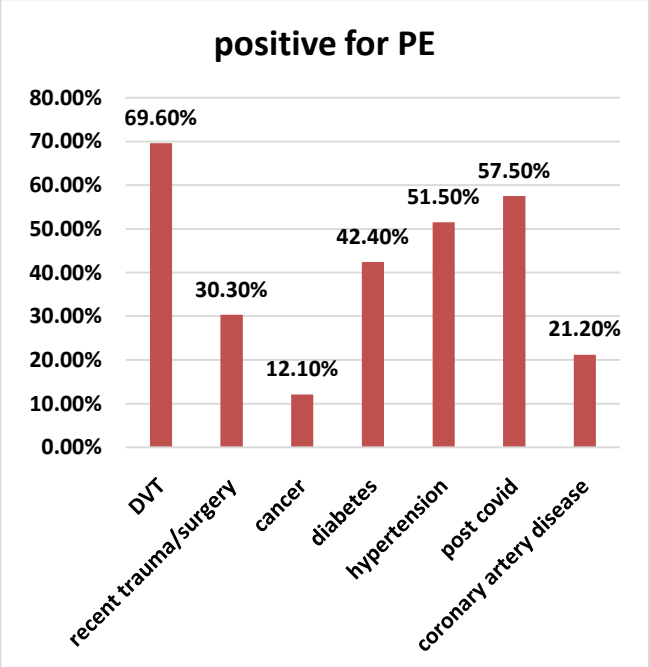

Figure 11: Distribution of risk factors in pulmonary embolism positive patients

Table 16: Distribution of Lung Involved of study participants

Lung Involved	Frequency	Percentage
Right	15	45.5
Left	4	12.1
Both	14	42.4
Total	33	100.0

In our study, 33 (33.0%) participants had lung involvement. Among these 15 (45.5%) participants were right lung involved, 4 (12.1%) were left and 14 (42.4%) were right and left lung involved.

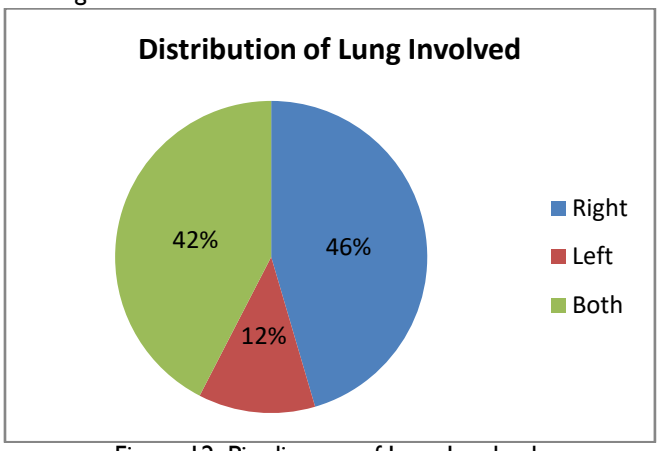

Figure 12: Pie diagram of Lung Involved

Table 17: Distribution of Involved Pulmonary Artery of study participants

Involved Pulmonary Artery	Frequency (n=33)	Percentage
Right Pulmonary Artery	11	33.4
Left Pulmonary Artery	12	36.4
Lobar Artery	1	3.0
Segmental Artery	14	42.4
Subsegmental	6	18.1

Out of 33 participants with pulmonary artery involvement, 11 (33.4%) were right pulmonary artery, 12 (36.4%) were left pulmonary artery, 1 (3.0%) were lobar artery, 14(42.4%) were segmental artery and 16 (18.1%) were sub segmental artery.

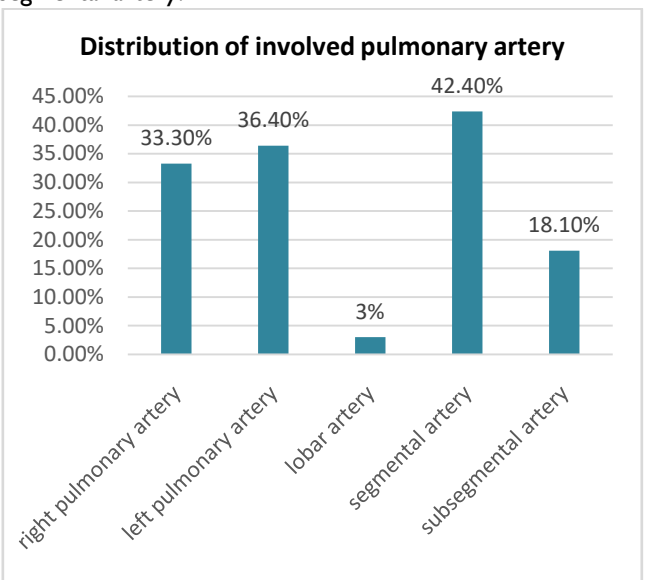

Fig 13: Distribution of Involved Pulmonary Artery of study participants

Table 18: Distribution of Lobes involved of study participants

Lobes Involved	Frequency (n=33)	Percentage
Right Upper Lobe	13	39.3%
Right Middle Lobe	16	48.4%
Right Lower Lobe	25	75.7%
Left Upper Lobe	17	51.5%
Left Lower Lobe	17	51.5%

Out of 33 participants with involvement of lobes, 13 (39.3%) were right upper lobe involvement, 16 (48.4%) were right middle lobe, 25 (75.7%) were right lower lobe, 17(51.5%) were left lower lobe and 17 (51.5%) were left lower lobe involvement.

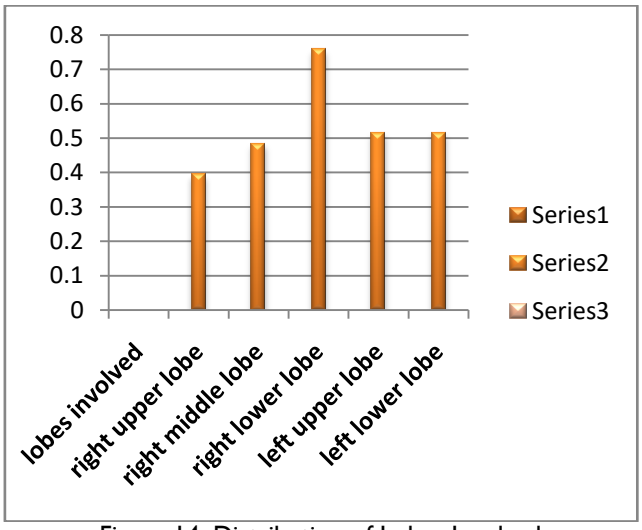

Figure 14: Distribution of Lobes Involved

Table 19: Chest radiograph findings and their association with presence or absence of pulmonary embolism

Chest radiograph findings.	Pulmonary embolism			
	Present		Absent	
	n=33	%	n=67	%
Normal	6	18.1%	35	52.2%
Pleural effusion	16	48.4%	16	48.4%
cardiomegaly	7	21.2%	15	22.3%
bronchopneumonia	1	3%	1	1.5%
Parenchymal opacities	18	54.5%	10	14.9%

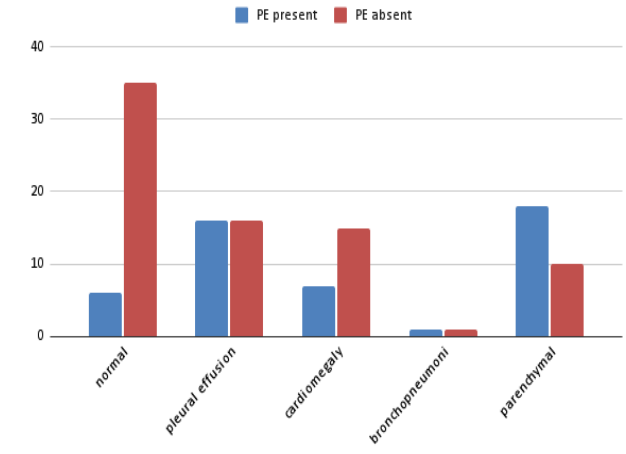

Fig 15: Bar diagram showing chest radiograph findings and their association with presence or absence of PE.

Table 20: CT findings and their association between absence or presence of pulmonary embolism

CT Findings	Pulmonary embolism			
	Present		Absent	
	n=33	%	n=67	%
Normal	2	6%	33	49.2%
Cardiomegaly	12	36.3%	13	19.4%
Pleural effusion	17	51.5%	24	35.8%
Pericardial Effusion	14	42.4%	6	8.9%
parenchymal Opacities	30	90.9%	14	20.8%
Enlarged Mediastinal Lymph nodes	0	0.0	4	5.9%

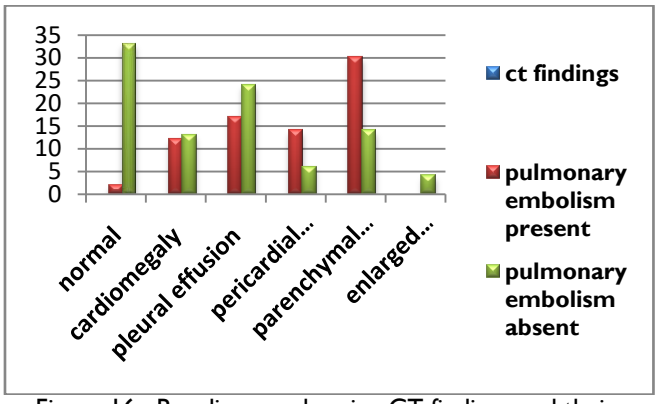

Figure 16: Bar diagram showing CT findings and their association with presence or absence of PE.

Table 21: Incidental vascular findings and their association with PAOI

Variables	PAOI				χ^2 Value	p Value
	>33		≤33			
	n=15	%	n=18	%		
DPA	11	73.3	4	22.2	6.683	0.010
CAL-vessels	4	26.7	5	27.8	0.000	1.000

Dilated pulmonary artery showed 73.0% (11/15) in pulmonary artery obstruction index value more than 33 and 22.2% (4/18) in less than or equal to 33. The p value revealed that PAOI statistically associated with Dilated pulmonary artery. Calcification of aorta and coronary arteries showed only 26.7% (4/15) in pulmonary artery obstruction index value more than 33 and 27.8% (5/18) in less than or equal to 33. The p value revealed that PAOI statistically not associated with Calcification of aorta and coronary arteries.

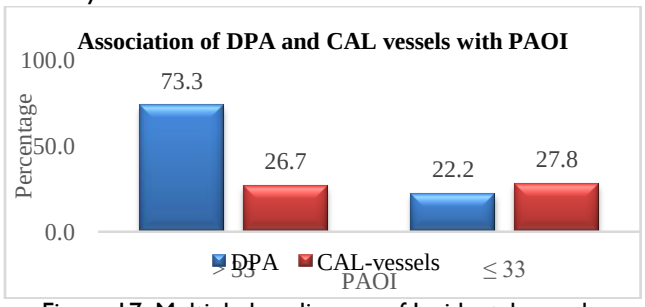

Figure 17: Multiple bar diagram of Incidental vascular findings with PAOI

DISCUSSION

The present study is a cross sectional study to evaluate suspected pulmonary embolism cases using multidetector computed tomographic pulmonary angiography (CTPA). Early detection of pulmonary embolism is necessary to reduce the mortality and morbidity. The objectives were to find out the prevalence of pulmonary embolism and to compare the findings of CTPA with d-dimer assays, to find out the associations of CTPA findings with pulmonary artery obstruction index (PAOI) using quandli score. The severity of PE is established using pulmonary artery obstruction index using quandli score and associated parameters were assessed using appropriate statistical tools. A total of 100 suspected cases (Table 03) of PE cases were included in the study as per the inclusion criteria. CTPA reported that 33 (33%) of them were positive for pulmonary embolus while remaining 67 (67%) were negative for embolus. In a study conducted by Nduta et al67, 27% were found to have embolus on multidetector computed pulmonary angiography. Burkill GJ et al68 showed that CTPA was positive for 28 out of 101 patients. Quandlisd et al 69 performed CTPA on 158 patients and out of which 54 (34%) were proven to have pulmonary embolism. In a similar study done by Attia NM et al8, among 70 suspected case 35 (50%) patients were positive for pulmonary embolism. Thus, the prevalence rate of pulmonary embolism in our study (33%) is comparable to previous studies in literature. Our study group was divided in to 5 age groups, < 30years, 30-39, 40-49, 50-59 and >60 years (Table 04 & 05). It was observed that majority of patients with suspected pulmonary embolism were found in elderly more than 60 years of age (60%). Majority of pulmonary embolism negative patients also belongs to age more than 60 years. None of the patients of age less than 30 years and between 40 to 49 years were positive for pulmonary embolism. While age group 30 to 39 constitutes 1 (5%) patient, 50 to 59 age group constitutes 12 patients (36.4%). This data was comparable with the studies conducted by *Nduta et al [*67*], Rodrigues B et al [*70*], Hefeda et al [*71*], Kang DK et al [*72*] and Ahmed DS et al [*73]. Out of 100 patients in our study, male to female ratio was 1:1 (Table 6 & 7). But the proportion of pulmonary embolism positive cases were higher in males 26 (78.8%) compared to females 7(21.2%). Thus, male to female ratio in PE positive and negative patients was found to be 3.7:1 and 0.55:1 respectively, showing significant statistical association of male gender with pulmonary embolism. We could find similar results in literature also. A study done by Kang DK et al showed that majority of PE positive cases were males (53%). Similar observations were made in study done by *Hefeda MM et al [*71] also where most of PE positive cases were males (65%). In contrast, *Nduta et al [*67] reported a female predominance in male to female ratio in PE positive and PE negative patients (1:2 and 1:2.1 respectively). Other studies done by *Rodrigues et al [*70], (63%), *Ahmad et al* (57%) [73], selimoglusen *H* et al 74 (60%) also shows female predominance in pulmonary embolism positive cases. Of total 100 patients on whom CTPA was performed, 67% showed no signs of occlusion and hence graded as score 0, while 30% showed partial occlusion graded as score 1 and 3% showed total occlusion (Table 8) graded as score 2. Based on number of arteries involved 67% scored 0, 10% scored between 1-5, 8% scored between 6-10 and majority that is 15% positive for pulmonary embolism scored between 11-20. Hence a zero score on occlusion and non-involvement of arteries denote absence of pulmonary embolism on CTPA.

The use of quandli score to determine pulmonary artery obstruction index (PAOI) is shown. An optimal cut off value of 13 for qanadli score which is equivalent to 33% of PAOI was established after constructing an ROC curve. The sensitivity and specificity values were 78.9% and 100% respectively. Thus total of 33 PE positive patients were divided into two groups; one group of PAOI ≤ 33% (n=20, 60.6%) and other group of PAOI between 33%-100% (n=13,39.3%).

Different studies done to evaluate pulmonary embolism by CTPA have used different cut off for Quandli score or PAOI. Studies conducted by *Rodrigues B et* al [70], and *Hefeda MM et al [*71], had established a cut off value of 18 for Quandli score based on ROC curve which corresponds to 45% PAOI. *Attia NM et al [*8], constructed ROC curve to establish cut off value of 43% for PAOI. Similarly, the cut off value kept by *Selimoglusen H et al* [74] *and Mehmet Burak Cildag et al* [75] was 38.5% and 23.75% respectively in their studies. In our study cut off value was 33%.

In our study, the most common presenting symptoms were dyspnea 100% followed by cough in 80%, chest pain in 36%, lower limb edema in 26% and fever in 18% (Table 13). Comparing the clinical presentations of the patients in two PAOI group, equal prevalence of dyspnoea were seen in both the groups. There was a higher prevalence of cough, chest pain and fever in PAOI >33-100% group. All the observed differences were found to be statistically insignificant. As per study conducted by *Qiao-ying ji et al*[76] dyspnea (64.1%) and cough (60.4%) were the most common clinical presentations in patients presented with pulmonary embolism which was similar to our study. *Nduta DW et al*[67] also reported that commonest clinical presentation of patients referred for CTPA was dyspnea (100%) , followed by chest pain (27%) and cough (13%) , however there was no significant association with pulmonary embolism status.

Considering the prevalence of risk factors, 69.6% of patients with pulmonary embolism had deep vein thrombosis followed by post covid history 57.5% and hypertension 51.5% (Table 14 & 15). Prevalence of risk factors like diabetes, hypertension, post covid, coronary artery disease etc were slightly higher in PAOI <33% group whereas others like DVT, recent surgical history and trauma were slightly higher in PAOI >33%. But the differences were statistically not significant. *Rodrigues B et al*[70] also reported that no significant association exists between the clinical presentation at admission and QS score. The majority of risk variables were more prevalent in the QS>18 group, according to the same study, however this finding lacked statistical significance.

In our study, 67 patients (67%) were positive for D-dimer assays and remaining 33% were negative for the same. 29 cases (87.9 %) of PE positive had a positive D-dimer assays. 4% of PE positive cases were negative for pulmonary embolism. However, 38% of D-dimer positive cases were negative for pulmonary embolism. As a result, D-dimer assay has an 87.8% negative predictive value. Consequently, statistical evidence links the D-dimer readings to pulmonary embolism. As per study conducted by *Hui Gao et [*77], al D-dimer values were significantly higher in patients positive

for PE on CTPA. Similar study done by Mateuzs Piotr kubak et al [78], showed that elevated D-dimer cut-off achieved high sensitivity and NPV and reducing the number of CTPA by 27%. In contrast to these study findings, Leila Salehi et al [79], showed that D -dimer values have no statistically significant association. Also, many studies have shown that D-dimer specificity and growing older have an antagonistic relationship. Therefore, the performance of D-dimer assay could be enhanced by excluding older patients in suspected pulmonary embolism.

Association between CTPA findings for ventricular dysfunction and PAOI is presented in table -12. It was observed that in PAOI ≤33% group; the proportion of ratio of right ventricular diameter to left ventricular diameter (Rvd/Lvd), ratio of pulmonary artery diameter aorta diameter (Pad/Aod), and pulmonary trunk diameter (Ptd>29mm) was 22.2%, 22.2% and 16.6% each. While in PAOI >33-100% group, the proportion of cases with Rvd/Lvd>1, Pad/Aod>1, and Ptd>29mm was found to be 86.6% in each. The proportion of interventricular septal bowing towards the left ventricle (IVS bowing) and inferior vena cava reflux in PAOI> 33-100% group was 53.3% and 21.2% respectively, whereas the proportion of same in PAOI≤ 33% was 0% each. Statistical analysis confirmed that proportion of Rvd/Lvd>1, Pad/Aod>1, Ptd>29mm and IVS bowing was significantly increases with increase in PAOI.

A ratio of right ventricle to left ventricular diameter greater than 1 which is an indication of right ventricular strain due to pulmonary hypertension attributable to PE. CTPA results in a study conducted by *Rodrigues B et al*70 showed significantly higher Rvd/Lvd ratio, IVS bowing and IVC reflux in QS>18 ;whereas PA diameter and PaD/AoD ratio was almost similar to QS>18 and QS<18 groups. Another study done by *Hefeda MM et al [*71], reported that Rvd/Lvd ratio was significantly higher in Qs>18 group while PaD/AoD ratio was non-significantly higher in QS>18 group. In a study conducted by *Attia NM et al [*8], mean PAOI was significantly higher with increasing Rvd/Lvd ratio and with increasing pulmonary artery diameter.

*Lim et al [*80], found a RvD/LvD ratio of greater than 1 measured on axial sections indicative of RV strain on CTPA. Reflux of contrast into IVC is an indirect sign of tricuspid valve insufficiency, frequently observed in right heart failure. Nevertheless, *collombet et al* [81], found that this sign is not different from patients with severe and non-severe PE patients. The interventricular septum, which bows towards the RV, may shift towards LV related to increased right heart pressure in case of severe pulmonary arterial obstruction. Septal bowing is not specific for acute PE and can be found in numerous disorders resulting in increased pulmonary artery pressure.

Our study revealed that out of 33 PE positive patients, 15(45.5%) participants had right lung involvement, 4(12.1%) had left lung involvement and 14(42.4%) were having both lungs involved (Table 16). Out of lung lobes affected, maximum involvement was noted in right lower lobe-25 cases (75.7%) whereas least involved lobe was right upper lobe 13 cases (39.3%). Similarly, *Ghazi Alshumrani et al [*52], also showed that right lower lobe is more affected area (55%) and left upper lobe is least affected one (41%). *Jianpu Chen et al*82 showed that more involved lobe is right lower lobe (70%) and less involved is right middle lobe (20%). In our study, PE was more localized in the segmental pulmonary artery (42.4%) followed by left main pulmonary artery (36.4), and then right pulmonary artery (33.3%). Least involved was lobar artery (3%) (Table 17). As per study conducted by *Supikakristaneepaiboon et al [*59], pulmonary embolism was localized more in lobar pulmonary artery (39%), and less in sub segmental artery (16%) which is contrast to this study. In a study conducted by *Ghazi alshumrani et al* [52], more common involved artery is segmental branches (86%).

Table 19 describes the chest radiograph and their association with PE positive and negative cases. The proportion of cases with pleural effusion and bronchopneumonia were almost similar in pulmonary embolism positive and negative cases (48.4%). Prevalence of parenchymal opacities was higher in PE positive cases (54.5%). However, all the observed differences were found to be statistically not significant.

Table 20 describes the CT findings and their association with presence or absence of pulmonary embolism. The prevalence of parenchymal opacities (90.9%), pleural effusion (51.5%), pericardial effusion (42.4%) and cardiomegaly (36.3%) were higher in PE positive cases. However, all the observed differences were found to be statistically not significant.

Incidental vascular findings in both PAOI groups is shown in Table 21. Cases with dilated pulmonary artery (73.3%) were more in PAOI>33-100% group whereas only 22.2% cases in group ≤ 33% showed dilated pulmonary artery. PAOI was found to be statistically associated with dilated pulmonary artery whereas its association with calcification of aorta and coronary arteries were found to be insignificant. Most frequent vascular abnormalities according to *Ahmad Ds et al [*73], were calcifications of major vessels and dilatation of pulmonary trunk. Pulmonary artery dilatation often indicates pulmonary arterial hypertension.

CONCLUSION

Computed tomographic pulmonary angiography (CTPA) is the imaging modality of choice for the diagnosis of pulmonary embolism. Aim of present study was to assess the suspected PE patients with CTPA and determine whether there was any correlation between CTPA findings, laboratory results and clinical presentation with pulmonary artery obstruction index. PAOI can be considered as a fast and promising parameter for risk assessment in patients with pulmonary embolism. In this study a cut off value of 33% was obtained and was set for risk stratification and comparing with other parameters. Evidence of right ventricular strain in PE is evidenced by increased right ventricular to left ventricular diameter ratio (>1) on CTPA which was significantly associated with PAOI. In this study, CTPA also hoped to offer the advantage of delineating other vascular findings besides PE that might explains the patient presentation. Presence or absence of pulmonary embolism was not statistically associated with other positive chest radiograph findings and CT findings. Presence of pulmonary embolism was higher in patients having risk factors like deep venous thrombosis and post covid history. Presence of pulmonary embolism was higher in patients positive for D-dimer values. Hence a D-dimer assay can be the most usefully employed investigation in avoidance of further investigations. When the pretest probability of a PE is high based on history, clinical examination and cardiorespiratory measurements, a positive D-dimer may suggest the possibility of pulmonary

embolism especially in patients in whom CTPA is contraindicated.

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 repeated evaluation. With greater education of clinicians in this radiological system of scoring, rapid assessment for diagnosis, clinical risk evaluation and prognosis may be possible in emergency services.

FUNDING
Nil

AUTHOR CONTRIBUTION
All authors are contributed equally.

CONFLICT OF INTEREST
Not Declared

ACKNOWLEDGEMNET
Not Declared

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