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Original Research Article

Role of CT Pulmonary Angiography in Diagnosis of Acute Pulmonary Embolism - A Retrospective Cross-Sectional Observational Study in Tertiary Care Center

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Abstract: ***Background:*** Acute pulmonary embolism (PE) is a life-threatening condition requiring prompt diagnosis and assessment of disease severity. CT pulmonary angiography (CTPA) enables direct visualisation of pulmonary arterial thrombi and evaluation of right ventricular strain and alternative thoracic abnormalities. ***Aim:*** To evaluate the role of CTPA in diagnosing acute PE and characterising thrombus distribution, pulmonary arterial obstruction, right ventricular strain and additional thoracic findings. ***Methods:*** This retrospective cross-sectional observational study included 120 patients clinically suspected of acute PE who underwent CTPA at a tertiary care centre. CTPA findings were assessed for the presence and anatomical distribution of emboli, Qanadli CT obstruction index (CTOI), CT markers of right ventricular strain and alternative diagnoses. Clinical characteristics and Wells score categories were compared with CTPA findings. ***Results:*** PE was detected in 22 patients (18.3%). Among the 98 PE-negative patients, alternative thoracic abnormalities were identified in 70 (71.4%). Dyspnoea, tachycardia, previous deep vein thrombosis or PE, prolonged immobilisation, higher heart rate and lower oxygen saturation were significantly associated with PE. CTPA positivity increased from 3.7% in the low Wells score category to 22.4% in the intermediate and 52.9% in the high category ($p<0.001$). Segmental involvement (45.5%) and bilateral disease (59.1%) were the predominant patterns. Mean CTOI was 23.7 ± 15.2%. Central PE showed higher CTOI and greater right ventricular strain than peripheral PE. CTOI correlated strongly with the right-to-left ventricular diameter ratio (Spearman's $r_s=0.951$; $p<0.001$). ***Conclusion:*** CTPA provided diagnostic and anatomical characterisation of acute PE, enabled assessment of pulmonary arterial obstruction and right ventricular strain, and identified alternative thoracic abnormalities. Its integration with clinical probability assessment may support comprehensive evaluation of patients with suspected PE.

Keywords: CT pulmonary angiography.

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INTRODUCTION

Acute pulmonary embolism (PE) is a potentially life-threatening manifestation of venous thromboembolism that occurs when thrombotic material, most commonly originating from the deep veins of the lower limbs, travels through the venous circulation and lodges within the pulmonary arterial tree. It represents an important cause of cardiovascular morbidity and mortality worldwide. The clinical presentation varies considerably, ranging from asymptomatic or mildly symptomatic disease to severe respiratory distress, haemodynamic instability and sudden death. [1,2] The variable and often nonspecific clinical presentation makes early diagnosis challenging and necessitates an appropriate combination of clinical assessment, laboratory investigations and imaging techniques.

The symptoms of acute PE commonly include dyspnoea, pleuritic chest pain, cough, haemoptysis,

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syncope and tachycardia. However, these manifestations may overlap with several other cardiopulmonary conditions, including pneumonia, congestive heart failure, chronic obstructive pulmonary disease and acute coronary syndromes.[3] Clinical risk factors such as previous deep vein thrombosis or pulmonary embolism, prolonged immobilisation, recent surgery, active malignancy and cardiac disease increase the likelihood of thromboembolic events. Since clinical findings alone are insufficient to establish or exclude the diagnosis reliably, structured assessment of pretest probability plays an important role in the diagnostic pathway. The Wells clinical prediction rule is widely used to classify patients according to their probability of having PE and helps guide subsequent investigations.[4]

Imaging plays a central role in confirming acute pulmonary embolism. Earlier diagnostic approaches included ventilation-perfusion scintigraphy and conventional pulmonary angiography. With advances in multidetector computed tomography, CT pulmonary angiography has become the principal imaging modality for evaluating suspected acute PE. The Prospective Investigation of Pulmonary Embolism Diagnosis II (PIOPED II) study demonstrated the diagnostic accuracy of multidetector CT angiography and also highlighted the importance of interpreting imaging findings in conjunction with clinical pretest probability.[5] The European Society of Cardiology guidelines recognise CTPA as the method of choice for imaging the pulmonary vasculature in patients with suspected PE, owing to its rapid acquisition, availability, high diagnostic accuracy and ability to demonstrate alternative thoracic abnormalities when embolism is excluded.[6]

On CTPA, acute pulmonary embolism is identified by the presence of an intraluminal filling defect within a contrast-opacified pulmonary artery. The thrombus may involve the main pulmonary artery, lobar, segmental or subsegmental branches. Apart from confirming the diagnosis, CTPA provides detailed information regarding the anatomical distribution and extent of thrombus. The Qanadli CT obstruction index is an established method for quantifying pulmonary arterial obstruction. It considers the number of affected segmental arteries and the degree of vascular obstruction, providing a numerical estimate of clot burden.[7] This quantitative assessment may contribute to the evaluation of disease severity when interpreted alongside clinical and cardiac parameters.

Acute pulmonary embolism can increase pulmonary vascular resistance and produce acute pressure overload of the right ventricle. Consequently, assessment of right ventricular dysfunction is an important component of risk stratification. CTPA permits evaluation of several imaging markers, including the right ventricular-to-left ventricular (RV/LV) diameter ratio, interventricular septal bowing and contrast reflux into the inferior vena cava. An increased RV/LV ratio has been associated with right ventricular dysfunction and adverse clinical outcomes in patients with acute PE.[8,9] Previous studies have also evaluated the prognostic significance of right ventricular enlargement and pulmonary arterial obstruction assessed on CT. [10,11] The 2019 European Society of Cardiology guidelines emphasise the importance of right ventricular assessment in the risk stratification of patients with acute pulmonary embolism.[6]

Another important advantage of CTPA is its ability to identify alternative or incidental thoracic abnormalities in patients without demonstrable pulmonary embolism. Findings such as pneumonia, pleural effusion, atelectasis, pulmonary masses and other cardiopulmonary abnormalities may provide an explanation for the presenting symptoms and assist subsequent clinical management. [6,12] Thus, the clinical usefulness of CTPA extends beyond the detection of pulmonary arterial thrombi.

In this context, the present study evaluated the role of CTPA in patients with clinically suspected acute pulmonary embolism at a tertiary care teaching hospital. It assessed the diagnostic yield of CTPA, anatomical distribution of thrombi, pulmonary arterial obstruction using the Qanadli index, associated right ventricular strain parameters and the relationship between Wells score categories and CTPA findings. The study also documented alternative thoracic diagnoses among patients with negative CTPA findings, providing a comprehensive assessment of the diagnostic contribution of CTPA in this clinical setting.

METHODOLOGY

A retrospective cross-sectional observational study was conducted in the Department of Radiodiagnosis, Byramjee Jeejeebhoy Government Medical College and Sassoon General Hospital, Pune, over a period of 18 months. A total of 120 adult patients with clinical suspicion of acute pulmonary embolism who underwent CTPA were included through convenience sampling. The sample size was calculated using Cochran's formula, considering an estimated PE prevalence of 4%, a 95% confidence interval and a 4% margin of error. Patients with complete clinical records and available CTPA images were included, while those with serum creatinine above 1.5 mg/dL, pregnancy, previous adverse reactions to iodinated contrast or incomplete records were excluded. Clinical and demographic details, presenting symptoms, risk factors, vital parameters and Wells scores were retrieved from medical records. CTPA examinations were performed using a Siemens SOMATOM Definition AS 128-slice MDCT scanner with intravenous iodinated contrast and bolus tracking. Images were assessed for thrombus presence, anatomical distribution, laterality, lobar involvement, Qanadli CT obstruction index, right ventricular strain parameters and alternative thoracic

findings. Data were analysed using IBM SPSS version 26.0. Appropriate parametric or non-parametric tests, Chi-square or Fisher's exact test, Spearman correlation and Kruskal–Wallis test were applied. A two-tailed p-value below 0.05 was considered statistically significant

RESULT

Table 1: Diagnostic yield, technical adequacy and additional diagnostic findings of CTPA (n = 120)

Parameter	Category	Frequency (n)	Percentage (%)
CTPA findings	PE-positive	22	18.3
	PE-negative	98	81.7
Technical adequacy	Adequate	112	93.3
	Suboptimal but interpretable	5	4.2
	Non-diagnostic	3	2.5
Additional findings among PE-negative patients (n = 98)	Normal CT	28	28.6
	Pneumonia/consolidation	20	20.4
	Pleural effusion	10	10.2
	Cardiomegaly/heart failure	8	8.2
	Atelectasis	8	8.2
	Emphysema/COPD	6	6.1
	Ground-glass opacities	5	5.1
	Lung mass/nodule	4	4.1
	Lymphadenopathy	4	4.1
	Pericardial effusion	3	3.1
	Aortic aneurysm	2	2.0
	Total with additional findings	70	71.4

Table 2A: Comparison of demographic, clinical and risk-factor characteristics between PE-positive and PE-negative patients

Variable	PE-positive (n = 22)	PE-negative (n = 98)	p-value
Age (years), mean ± SD	56.3 ± 10.9	59.2 ± 17.0	0.504
Male sex, n (%)	11 (50.0)	42 (42.9)	0.710
Dyspnoea, n (%)	21 (95.5)	70 (71.4)	0.024
Chest pain, n (%)	12 (54.5)	55 (56.1)	1.000
Haemoptysis, n (%)	2 (9.1)	2 (2.0)	0.153
Tachycardia, n (%)	14 (63.6)	16 (16.3)	<0.001
Syncope, n (%)	2 (9.1)	3 (3.1)	0.227
Leg swelling, n (%)	7 (31.8)	14 (14.3)	0.100
Previous DVT/PE, n (%)	6 (27.3)	7 (7.1)	0.018
Active malignancy, n (%)	3 (13.6)	8 (8.2)	0.421
Prolonged immobilisation, n (%)	8 (36.4)	12 (12.2)	0.015
Cardiac disease, n (%)	6 (27.3)	21 (21.4)	0.756
Heart rate (beats/min), mean ± SD	106.8 ± 15.5	87.6 ± 13.8	<0.001
SpO_2 (%), mean ± SD	89.4 ± 4.9	95.1 ± 3.0	<0.001

Table 2B: Association between Wells score categories and CTPA findings

Wells score category	Total patients, n (%)	PE-positive, n (%)	PE-negative, n (%)	CTPA positivity (%)
Low (0–1)	54 (45.0)	2 (3.7)	52 (96.3)	3.7
Intermediate (2–6)	49 (40.8)	11 (22.4)	38 (77.6)	22.4
High (≥7)	17 (14.2)	9 (52.9)	8 (47.1)	52.9
Total	120 (100.0)	22 (18.3)	98 (81.7)	18.3

Table 3A: Most proximal level of pulmonary arterial thrombus in PE-positive patients (n = 22)

Most proximal level	Frequency (n)	Percentage (%)
Main pulmonary artery/saddle	3	13.6
Lobar	5	22.7
Segmental	10	45.5
Subsegmental	4	18.2
Total	22	100.0

Table 3B: Laterality of pulmonary embolism in PE-positive patients (n = 22)

Laterality	Frequency (n)	Percentage (%)
Bilateral	13	59.1
Right-sided	6	27.3
Left-sided	3	13.6
Total	22	100.0

Table 3C: Lobar distribution of pulmonary embolism in PE-positive patients (n = 22)

Pulmonary lobe involved	Frequency (n)	Percentage (%)
Right upper lobe (RUL)	7	31.8
Right middle lobe (RML)	7	31.8
Right lower lobe (RLL)	17	77.3
Left upper lobe (LUL)	4	18.2
Left lower lobe (LLL)	13	59.1

Table 3D: Qanadli CT obstruction index (CTOI) in PE-positive patients (n = 22)

CTOI category/measurement	Frequency (n) / Value	Percentage (%) / Range
Low (<20%)	10	45.5
Intermediate (20–40%)	8	36.4
High (>40%)	4	18.2
Total	22	100.0
Mean CTOI (%) ± SD	23.7 ± 15.2	—
Range (%)	4–55	—

Table 4A: Right ventricular strain parameters among PE-positive patients (n = 22)

Parameter	Category/measurement	Frequency (n) / Value	Percentage (%)
RV/LV ratio	Mean ± SD	1.1 ± 0.2	—
	>1.0	10	45.5
	≤1.0	12	54.5
Septal bowing	Present	6	27.3
	Absent	16	72.7
IVC contrast reflux	Grade I	9	40.9
	Grade II	5	22.7
	Grade III	8	36.4
Main pulmonary artery diameter	Mean ± SD (mm)	29.3 ± 3.5	—
	>29 mm	12	54.5
Coronary sinus diameter	Mean ± SD (mm)	9.8 ± 4.1	—
	>9 mm	8	36.4

Table 4B: Comparison of right ventricular strain parameters between central and peripheral pulmonary embolism

Parameter	Central PE (n = 8)	Peripheral PE (n = 14)	p-value
RV/LV ratio, mean ± SD	1.3 ± 0.2	0.9 ± 0.1	<0.001
RV/LV ratio >1.0, n (%)	7 (87.5)	3 (21.4)	0.006
Septal bowing, n (%)	5 (62.5)	1 (7.1)	0.011
Grade III IVC reflux, n (%)	5 (62.5)	3 (21.4)	0.081
Mean CTOI (%) ± SD	39.9 ± 11.0	14.4 ± 7.4	<0.001

Table 4C: Relationship between Qanadli CT obstruction index and RV/LV ratio

CTOI category	Number of patients (n)	Mean RV/LV ratio ± SD	RV/LV ratio >1.0, n (%)
Low (<20%)	10	0.9 ± 0.1	2 (20.0)
Intermediate (20–40%)	8	1.1 ± 0.1	4 (50.0)
High (>40%)	4	1.4 ± 0.1	4 (100.0)

Note: Spearman correlation coefficient (r_s) = 0.951, $p < 0.001$; Kruskal–Wallis test $p < 0.001$.

A total of 120 patients clinically suspected of having acute pulmonary embolism (PE) and referred for CT pulmonary angiography (CTPA) were included in the study. CTPA demonstrated pulmonary embolism in 22 patients (18.3%), whereas 98 patients (81.7%) had no evidence of pulmonary embolism. Thus, the overall

diagnostic yield of CTPA for detecting acute PE in the study population was 18.3%. Regarding technical adequacy, 112 examinations (93.3%) were considered adequate for interpretation, five (4.2%) were suboptimal but interpretable, and three (2.5%) were non-diagnostic. These findings indicate that the majority of CTPA examinations were technically adequate for assessment of pulmonary arterial thromboembolism. Among the 98 patients without PE, additional thoracic abnormalities were identified in 70 patients (71.4%), while 28 patients (28.6%) had no significant abnormality on CT. Pneumonia or consolidation was the most frequently observed additional finding, affecting 20 patients (20.4%), followed by pleural effusion in 10 patients (10.2%). Cardiomegaly or features of heart failure and atelectasis were each observed in eight patients (8.2%). Emphysema or COPD was identified in six patients (6.1%), while ground-glass opacities were observed in five patients (5.1%). Lung mass or nodule and lymphadenopathy were each detected in four patients (4.1%), pericardial effusion in three patients (3.1%), and aortic aneurysm in two patients (2.0%). These findings demonstrate that CTPA frequently identified alternative thoracic abnormalities among patients in whom PE was excluded, thereby providing additional diagnostic information.

The mean age of patients with PE was 56.3 ± 10.9 years, compared with 59.2 ± 17.0 years among patients without PE. Although the mean age was slightly lower in the PE-positive group, the difference was not statistically significant (p=0.504). Male patients constituted 50.0% of the PE-positive group and 42.9% of the PE-negative group, with no statistically significant difference in sex distribution (p=0.710). Dyspnoea was the predominant presenting symptom among patients with PE, reported in 21 patients (95.5%), compared with 70 patients (71.4%) without PE. This difference was statistically significant (p=0.024). Chest pain was reported in 12 patients (54.5%) with PE and 55 patients (56.1%) without PE, showing no significant association (p=1.000). Haemoptysis was observed in two patients (9.1%) in the PE-positive group and two patients (2.0%) in the PE-negative group; however, the difference was not statistically significant (p=0.153). Tachycardia was significantly more frequent among patients with PE, occurring in 14 patients (63.6%), compared with 16 patients (16.3%) without PE (p<0.001). Syncope was reported in two patients (9.1%) with PE and three patients (3.1%) without PE (p=0.227). Similarly, leg swelling was observed in seven patients (31.8%) with PE compared with 14 patients (14.3%) without PE, although this difference did not reach statistical significance (p=0.100).

Regarding predisposing risk factors, a previous history of deep vein thrombosis (DVT) or pulmonary embolism was significantly more common among patients with PE, being present in six patients (27.3%), compared with seven patients (7.1%) without PE (p=0.018). Prolonged immobilisation was also significantly associated with PE, occurring in eight patients (36.4%) in the PE-positive group compared with 12 patients (12.2%) in the PE-negative group (p=0.015). Active malignancy was documented in three patients (13.6%) with PE and eight patients (8.2%) without PE, with no statistically significant difference (p=0.421). Cardiac disease was present in six patients (27.3%) with PE and 21 patients (21.4%) without PE, which was also not statistically significant (p=0.756). The mean heart rate was considerably higher among patients with PE (106.8 ± 15.5 beats/min) than among those without PE (87.6 ± 13.8 beats/min), and this difference was highly statistically significant (p<0.001). Similarly, mean peripheral oxygen saturation was significantly lower in the PE-positive group (89.4 ± 4.9%) compared with the PE-negative group (95.1 ± 3.0%; p<0.001). Overall, dyspnoea, tachycardia, previous DVT or PE, prolonged immobilisation, higher heart rate and lower oxygen saturation demonstrated statistically significant associations with CTPA-confirmed PE in the present study.

Assessment of the relationship between Wells clinical probability scores and CTPA findings demonstrated a progressive increase in PE detection with increasing Wells score category. Among the 54 patients (45.0%) classified as having low clinical probability (Wells score 0–1), PE was detected in two patients (3.7%), whereas 52 patients (96.3%) had no evidence of PE. In the intermediate-probability category (Wells score 2–6), comprising 49 patients (40.8%), 11 patients (22.4%) were diagnosed with PE and 38 patients (77.6%) were PE-negative. Among the 17 patients (14.2%) with high clinical probability (Wells score ≥7), nine patients (52.9%) had PE on CTPA, while eight patients (47.1%) had no evidence of pulmonary embolism. The CTPA positivity rate therefore increased from 3.7% in the low-probability group to 22.4% in the intermediate-probability group and 52.9% in the high-probability group. The association between Wells score categories and CTPA findings was statistically significant (χ^2=21.87; p<0.001), indicating a significant relationship between the clinical probability of PE and its radiological confirmation.

Among the 22 patients diagnosed with PE on CTPA, the most proximal level of thrombus involvement was predominantly segmental, observed in 10 patients (45.5%). Lobar pulmonary arterial involvement was identified in five patients (22.7%), while four patients (18.2%) had subsegmental involvement. Main pulmonary artery or saddle embolism was observed in three patients (13.6%). Thus, segmental pulmonary arterial involvement represented the most frequent level of thrombus distribution in the study population, whereas main pulmonary artery or saddle embolism was comparatively less common. Assessment of laterality revealed bilateral pulmonary arterial involvement in 13 patients (59.1%), making it the most frequent pattern.

Right-sided involvement was observed in six patients (27.3%), while three patients (13.6%) had left-sided involvement. These findings indicate that bilateral involvement was more frequently encountered than isolated unilateral involvement among patients with PE.

Analysis of the lobar distribution of pulmonary emboli revealed that the right lower lobe was the most frequently affected region, with involvement in 17 patients (77.3%). The left lower lobe was involved in 13 patients (59.1%). The right upper lobe and right middle lobe were each affected in seven patients (31.8%), whereas the left upper lobe was involved in four patients (18.2%). The lower lobes, particularly the right lower lobe, therefore demonstrated a greater frequency of thrombus involvement in the study population. Since individual patients could have thrombi involving more than one pulmonary lobe, the percentages for lobar distribution were not mutually exclusive and the total exceeded 100%.

The severity of pulmonary arterial obstruction was assessed using the Qanadli CT obstruction index (CTOI). The mean CTOI among the 22 PE-positive patients was 23.7 ± 15.2%, with values ranging from 4% to 55%. A low degree of pulmonary arterial obstruction (CTOI less than 20%) was observed in 10 patients (45.5%), representing the largest category. An intermediate degree of obstruction (20–40%) was observed in eight patients (36.4%), while a high degree of obstruction (greater than 40%) was identified in four patients (18.2%). Thus, most patients demonstrated low-to-intermediate pulmonary arterial obstruction, while fewer patients had a high obstruction burden.

Evaluation of CT indicators of right ventricular strain among the 22 PE-positive patients revealed a mean right ventricular to left ventricular (RV/LV) diameter ratio of 1.1 ± 0.2. An RV/LV ratio greater than 1.0, indicating right ventricular enlargement, was observed in 10 patients (45.5%), whereas 12 patients (54.5%) had an RV/LV ratio of 1.0 or less. Interventricular septal bowing was present in six patients (27.3%) and absent in 16 patients (72.7%). Assessment of inferior vena cava (IVC) contrast reflux showed Grade I reflux in nine patients (40.9%), Grade II reflux in five patients (22.7%), and Grade III reflux in eight patients (36.4%). The mean main pulmonary artery diameter was 29.3 ± 3.5 mm, with a diameter greater than 29 mm observed in 12 patients (54.5%). The mean coronary sinus diameter was 9.8 ± 4.1 mm, and eight patients (36.4%) had a diameter greater than 9 mm. These findings demonstrate the presence of different CT markers suggestive of right-sided cardiac strain among patients with acute PE, with RV/LV enlargement and Grade III IVC reflux being observed in a considerable proportion of cases.

Comparison of right ventricular strain parameters between patients with central and peripheral PE demonstrated more pronounced right ventricular changes in patients with central embolism. The mean RV/LV ratio was significantly higher in patients with central PE (1.3 ± 0.2) compared with those with peripheral PE (0.9 ± 0.1), and the difference was highly statistically significant ($p<0.001$). An RV/LV ratio greater than 1.0 was observed in seven patients (87.5%) with central PE, compared with three patients (21.4%) with peripheral PE, demonstrating a statistically significant difference ($p=0.006$). Septal bowing was also more frequent in central PE, being present in five patients (62.5%), compared with one patient (7.1%) with peripheral PE ($p=0.011$). Grade III IVC contrast reflux was observed in five patients (62.5%) with central PE and three patients (21.4%) with peripheral PE. Although this finding was more frequent in central embolism, the difference was not statistically significant ($p=0.081$). The mean CTOI was substantially higher in central PE (39.9 ± 11.0%) than in peripheral PE (14.4 ± 7.4%), and this difference was highly statistically significant ($p<0.001$). These observations indicate that central pulmonary emboli were associated with a greater pulmonary arterial obstruction burden and more prominent CT features of right ventricular strain than peripheral emboli.

Further assessment of the relationship between pulmonary arterial obstruction and right ventricular enlargement demonstrated a progressive increase in RV/LV ratio with increasing CTOI category. Among patients with a low CTOI (less than 20%), the mean RV/LV ratio was 0.9 ± 0.1, and two patients (20.0%) had an RV/LV ratio greater than 1.0. In the intermediate CTOI category (20–40%), the mean RV/LV ratio increased to 1.1 ± 0.1, with four patients (50.0%) demonstrating an RV/LV ratio greater than 1.0. Among patients with high CTOI (greater than 40%), the mean RV/LV ratio was 1.4 ± 0.1, and all four patients (100%) demonstrated an RV/LV ratio greater than 1.0. The difference in RV/LV ratio across the three CTOI categories was statistically significant (Kruskal–Wallis $p<0.001$). Furthermore, a very strong positive correlation was observed between CTOI and RV/LV ratio (Spearman's $r_s=0.951$; $p<0.001$). This demonstrates that increasing pulmonary arterial obstruction was associated with progressively greater right ventricular enlargement in patients with acute PE.

DISCUSSION

In the present study, CT pulmonary angiography (CTPA) demonstrated acute pulmonary embolism (PE) in 22 of the 120 clinically suspected patients, accounting for an overall positivity rate of 18.3%. The remaining 81.7% of patients had no evidence of PE on CTPA. This finding highlights the importance of objective imaging confirmation in patients presenting with clinical features suggestive of pulmonary embolism, as symptoms such as dyspnoea, chest pain and tachycardia are not specific to this condition. CTPA has become an important imaging modality for the diagnosis

of acute PE because it permits direct visualisation of thrombi within the pulmonary arteries and provides additional information regarding the pulmonary parenchyma, mediastinum and cardiovascular structures. The PIOPED II study by Stein *et al.,* established the diagnostic value of multidetector CT in the evaluation of acute PE, supporting its role in contemporary diagnostic practice. [3,5]

In the present study, 93.3% of CTPA examinations were technically adequate, while 4.2% were suboptimal but interpretable and 2.5% were non-diagnostic. The high proportion of technically adequate examinations supports the practical utility of CTPA in routine clinical evaluation. An important observation was that 70 of the 98 patients without PE (71.4%) had alternative thoracic abnormalities. Pneumonia or consolidation was the most common additional finding, followed by pleural effusion, cardiomegaly or features of heart failure, and atelectasis. These findings demonstrate that CTPA can provide clinically relevant alternative diagnoses when pulmonary embolism is excluded. This is particularly useful because patients with suspected PE may present with overlapping clinical manifestations arising from several cardiopulmonary conditions. The ability of multidetector CT to evaluate pulmonary arteries as well as thoracic structures contributes to its diagnostic usefulness in this setting.[5]

The mean age of patients with PE was 56.3 ± 10.9 years, compared with 59.2 ± 17.0 years among patients without PE. The difference was not statistically significant. Similarly, sex distribution did not show a significant association with CTPA-confirmed PE. These findings suggest that age and sex alone were not useful discriminating factors in the present study population. Among the presenting symptoms, dyspnoea was significantly more frequent in patients with PE than in those without PE (95.5% versus 71.4%; p=0.024). Tachycardia was also significantly more common in the PE-positive group (63.6% versus 16.3%; p<0.001). In contrast, chest pain, haemoptysis, syncope and leg swelling did not demonstrate statistically significant differences between the groups. The high frequency of dyspnoea among patients with PE is consistent with the recognised clinical presentation of acute pulmonary embolism. However, the occurrence of similar symptoms among patients without PE emphasises the limitations of relying on individual clinical manifestations for diagnosis. Current guidelines therefore recommend combining clinical probability assessment with appropriate diagnostic investigations rather than depending on symptoms alone.[3]

Regarding predisposing factors, previous DVT or PE was significantly more frequent among patients with PE (27.3% versus 7.1%; p=0.018). Prolonged immobilisation was also significantly associated with PE (36.4% versus 12.2%; p=0.015). These observations are consistent with the established role of venous thromboembolism risk factors in the development of acute pulmonary embolism. Previous venous thromboembolism indicates an increased likelihood of recurrence, while prolonged immobilisation contributes to venous stasis and thrombus formation. The importance of recognising these risk factors is reflected in established clinical approaches to PE assessment and management. [3,4] In the present study, active malignancy and cardiac disease were not significantly associated with PE. However, the relatively small number of PE-positive patients should be considered when interpreting these findings.

The mean heart rate was significantly higher among patients with PE than among those without PE (106.8 ± 15.5 versus 87.6 ± 13.8 beats/min; p<0.001). Similarly, mean oxygen saturation was significantly lower in the PE-positive group (89.4 ± 4.9% versus 95.1 ± 3.0%; p<0.001). These findings indicate that tachycardia and hypoxaemia were important clinical features associated with CTPA-confirmed PE in the present study. Pulmonary arterial obstruction can lead to increased pulmonary vascular resistance, impaired pulmonary perfusion and ventilation-perfusion mismatch, resulting in hypoxaemia and cardiovascular stress. The observed differences in heart rate and oxygen saturation therefore support the clinical relevance of assessing physiological parameters in patients with suspected PE. Nevertheless, these parameters should be interpreted alongside clinical probability and imaging findings.[3]

An important finding was the significant association between Wells score categories and CTPA results (χ^2=21.87; p<0.001). The CTPA positivity rate increased progressively from 3.7% in patients with low clinical probability to 22.4% in those with intermediate probability and 52.9% in those with high clinical probability. This increasing trend demonstrates that patients with higher clinical probability were more likely to have PE confirmed on CTPA. The Wells clinical prediction model was developed to categorise patients according to their probability of pulmonary embolism and assist in selecting appropriate diagnostic investigations.[4] The findings of the present study support the clinical relevance of this probability-based approach. However, PE was also detected in patients with low clinical probability, indicating that a low Wells score alone cannot be considered sufficient to exclude PE in every patient. The results further support the use of clinical probability assessment in conjunction with appropriate diagnostic testing, as recommended by established guidelines.[3]

Among the 22 patients with CTPA-confirmed PE, segmental pulmonary arterial involvement was the most frequent pattern, accounting for 45.5% of cases, followed by lobar involvement in 22.7%, subsegmental involvement in 18.2% and main pulmonary artery or saddle embolism in 13.6%. Bilateral involvement was

observed in 59.1% of patients, whereas right-sided and left-sided involvement accounted for 27.3% and 13.6%, respectively. The predominance of segmental and bilateral involvement indicates that thrombus distribution was variable and was not restricted to the central pulmonary arteries. CTPA provides detailed anatomical visualisation of pulmonary arterial branches, allowing identification of the location and extent of thromboembolic disease.[5] The lobar distribution analysis showed that the right lower lobe was the most frequently involved region (77.3%), followed by the left lower lobe (59.1%). The right upper and middle lobes were each involved in 31.8% of patients, while the left upper lobe was involved in 18.2%. These findings provide a detailed description of the anatomical distribution of PE in the study population. Since multiple lobes could be involved in the same patient, the percentages were not mutually exclusive.

The Qanadli CT obstruction index was used to quantify the extent of pulmonary arterial obstruction. The mean CTOI was 23.7 ± 15.2%, with a range of 4–55%. Low obstruction burden was observed in 45.5% of patients, intermediate obstruction in 36.4%, and high obstruction in 18.2%. The Qanadli index provides a systematic method for quantifying pulmonary arterial obstruction based on the number of obstructed segmental arteries and the degree of obstruction.[7] In the present study, its application enabled objective assessment of thrombus burden beyond the simple identification of PE as present or absent. This quantitative assessment was particularly relevant when evaluating the relationship between the anatomical extent of embolism and CT indicators of right ventricular strain.

Assessment of right ventricular strain revealed a mean RV/LV ratio of 1.1 ± 0.2, with an RV/LV ratio greater than 1.0 in 45.5% of patients. Interventricular septal bowing was observed in 27.3% of cases. Grade III IVC contrast reflux was identified in 36.4% of patients, while the mean main pulmonary artery diameter was 29.3 ± 3.5 mm. These findings demonstrate that CT can provide information regarding right-sided cardiac changes in addition to pulmonary arterial thrombus detection. Right ventricular enlargement is an important imaging marker in acute PE because increased pulmonary vascular resistance may produce right ventricular pressure overload and dilatation. Previous studies have evaluated the prognostic significance of right ventricular enlargement and other CT parameters in patients with acute PE. Schoepf *et al.,* reported an association between right ventricular enlargement on chest CT and early mortality, while Mansencal *et al.,* investigated the role of helical CT in identifying right ventricular dysfunction. [8,10] The present study similarly demonstrates the usefulness of assessing RV/LV ratio and other CT markers of right ventricular strain, although clinical outcome and mortality associations were not evaluated in the supplied results.

Comparison of central and peripheral PE revealed significantly greater right ventricular strain in patients with central embolism. The mean RV/LV ratio was higher in central PE than in peripheral PE (1.3 ± 0.2 versus 0.9 ± 0.1; $p<0.001$). An RV/LV ratio greater than 1.0 was observed in 87.5% of patients with central PE compared with 21.4% of those with peripheral PE ($p=0.006$). Septal bowing was also significantly more frequent in central PE (62.5% versus 7.1%; $p=0.011$). Although Grade III IVC contrast reflux was more frequently observed in central PE, the difference was not statistically significant ($p=0.081$). Furthermore, the mean CTOI was significantly higher in central PE than in peripheral PE (39.9 ± 11.0% versus 14.4 ± 7.4%; $p<0.001$). These findings suggest that central emboli were associated with a greater pulmonary arterial obstruction burden and more prominent CT indicators of right ventricular strain. Previous investigations by van der Meer *et al.,* and Ghuysen *et al.,* have also examined the relationship between pulmonary obstruction, right ventricular dysfunction and the prognostic significance of CT findings in acute PE. [9,11] The present findings are consistent with the importance of evaluating both thrombus location and right ventricular changes during CTPA interpretation.

A particularly important observation was the strong positive correlation between CTOI and RV/LV ratio (Spearman's $r_s=0.951$; $p<0.001$). The mean RV/LV ratio increased progressively from 0.9 ± 0.1 in patients with low CTOI to 1.1 ± 0.1 in those with intermediate CTOI and 1.4 ± 0.1 in those with high CTOI. The proportion of patients with an RV/LV ratio greater than 1.0 also increased from 20.0% in the low-obstruction group to 50.0% in the intermediate group and 100% in the high-obstruction group. The difference in RV/LV ratio across CTOI categories was statistically significant (Kruskal–Wallis $p<0.001$). This strong relationship indicates that greater pulmonary arterial obstruction was associated with greater right ventricular enlargement in the present study. The findings support the combined assessment of pulmonary arterial obstruction and right ventricular dimensions during CTPA evaluation. Previous studies have investigated the relationship between CT obstruction indices and right ventricular dysfunction, highlighting the value of quantitative CT assessment in acute PE. [7,9]

Overall, the findings of the present study demonstrate that CTPA is useful not only for confirming acute pulmonary embolism but also for defining thrombus distribution, quantifying pulmonary arterial obstruction, assessing right ventricular strain and identifying alternative thoracic abnormalities. The significant association between Wells score categories and CTPA findings supports the integration of clinical probability assessment with imaging. Furthermore, the observed relationship between CTOI and RV/LV ratio highlights the importance of evaluating both clot burden and right ventricular changes in patients with confirmed

PE. These findings are in agreement with the established role of CTPA in the diagnosis and imaging-based assessment of acute pulmonary embolism. [3,5,7]

CONCLUSION

CT pulmonary angiography proved useful in diagnosing acute pulmonary embolism, defining thrombus distribution, quantifying pulmonary arterial obstruction and identifying right ventricular strain. Higher Wells scores were significantly associated with CTPA positivity, while central PE and greater obstruction burden were associated with more prominent right ventricular changes. CTPA also identified alternative thoracic abnormalities in a substantial proportion of patients without PE, highlighting its comprehensive diagnostic value.

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