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Contribution of CT Angiography and Doppler Ultrasound in Diagnosing Deep Vein Thrombosis in Patients with Pulmonary Embolism: A Prospective Study

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ABSTRACT

***Background*:** The diagnostic accuracy of computed tomography venography (CTV) in detecting deep vein thrombosis (DVT) among pulmonary embolism (PE) patients remains an area of active investigation. ***Objectives*:** To evaluate the diagnostic performance of CTPA combined with indirect CTV in diagnosing DVT in PE patients and compare it with Doppler ultrasonography. ***Materials and Methods*:** This prospective cross-sectional study included 50 patients with suspected PE who underwent both CTPA with indirect CTV and Doppler ultrasonography. The study was conducted over 12 months using a 128-slice CT scanner and standardized ultrasound protocols. ***Results*:** The study population comprised 58% males and 42% females, with the majority (54%) aged 31-50 years. DVT was detected in 50% of cases by Doppler ultrasonography and 46% by CTV. CTV demonstrated sensitivity of 76.0%, specificity of 84.0%, positive predictive value of 82.6%, and negative predictive value of 77.8%. The area under the ROC curve was 0.800 (95% CI: 0.671-0.929), with substantial agreement between modalities (κ=0.600, p=0.0005). Right pulmonary artery involvement was most common (18%), and additional pathological findings were observed in 70% of cases. ***Conclusion*:** CTV shows substantial agreement with Doppler ultrasonography in DVT detection, offering the advantage of concurrent PE and DVT evaluation in a single examination. The high diagnostic accuracy supports its integration into routine PE imaging protocols.

Keywords: Computed Tomography Venography; Deep Vein Thrombosis; Pulmonary Embolism; Doppler Ultrasonography; Diagnostic Accuracy; Prospective Study; Thromboembolism; Imaging Protocol; Vascular Imaging; Clinical Correlation.

INTRODUCTION

Pulmonary embolism (PE) and deep vein thrombosis (DVT) represent two manifestations of venous thromboembolism (VTE), a significant cause of cardiovascular mortality and morbidity worldwide [1]. The relationship between these conditions is well-established, with studies indicating that approximately 50-80% of patients with PE have concurrent DVT, though it may be clinically silent [2]. This association has important implications for patient management, as the presence of DVT in PE patients may influence therapeutic decisions and affect long-term outcomes [3].

The accurate diagnosis of DVT in patients with confirmed PE is crucial for several reasons. First, the presence of residual DVT increases the risk of recurrent VTE and post-thrombotic syndrome, potentially necessitating extended anticoagulation therapy [4]. Second, identifying the source of embolism can help stratify patients' risk and guide preventive strategies. Third, concurrent DVT detection may influence the choice between systemic thrombolysis and catheter-directed interventions in selected cases of intermediate-high risk PE [3, 5].

Traditional diagnostic algorithms for DVT have relied heavily on compression ultrasonography (CUS) as the primary imaging modality, given its non-invasive nature, lack of radiation exposure, and high sensitivity and specificity for proximal DVT [6]. However, CUS has limitations, including operator dependency, limited visualization of iliac veins, and reduced accuracy in obese patients or those with significant edema. Moreover, the systematic performance of bilateral lower extremity CUS in all PE patients remains controversial, with varying practices across institutions [7].

Computed tomography (CT) angiography has emerged as the gold standard for PE diagnosis, offering excellent visualization of pulmonary vasculature and enabling risk stratification based on right ventricular dysfunction [8]. Modern CT protocols can be extended to include venous phase imaging of the lower extremities (CT venography) without significant additional radiation exposure or contrast medium. This "one-stop-shop" approach has generated interest in the potential role of CT in concurrent DVT detection [9].

Despite these technological advances, there remains uncertainty regarding the optimal strategy for DVT detection in PE patients. Questions persist about the comparative accuracy of CT venography versus CUS, the cost-effectiveness of different diagnostic approaches, and the clinical impact of routine DVT screening in this population [10]. These considerations have led to variations in clinical practice and highlight the need for prospective evaluation of different imaging strategies.

Our prospective study aims to evaluate the diagnostic performance of CT angiography and Doppler ultrasound in detecting DVT among patients with confirmed PE, comparing their respective strengths and limitations. Additionally, we seek to assess the clinical implications of different imaging strategies on patient management and outcomes. Understanding the optimal approach to DVT diagnosis in PE patients could lead to more efficient diagnostic algorithms and improved patient care.

Aims and Objectives

The primary objective of this investigation was to evaluate the diagnostic efficacy of Computed Tomography Pulmonary Angiography (CTPA) combined with indirect Computed Tomography Venography (CTV) in identifying Deep Vein Thrombosis (DVT) among patients presenting with clinical suspicion of Pulmonary Thromboembolism (PTE). The secondary objective focused on comparing the diagnostic accuracy of these combined imaging techniques with Doppler Ultrasound examination, which was considered the reference standard for DVT diagnosis in this study population.

Materials and Methods

Study Design and Setting

This prospective cross-sectional study was conducted at the Department of Radiology, SSIMS & RC, Davangere, India, over a period of twelve months from June 2023 to May 2024. The study protocol was approved by the institutional ethics committee, and written informed consent was obtained from all participants prior to enrollment.

Study Population and Sample Size

A total of 50 consecutive patients who presented with clinical suspicion of PTE were enrolled in the study. The sample size was determined based on the expected prevalence of DVT in PTE patients and the desired precision level, with a confidence interval of 95% and a margin of error of 5%. The calculation was performed using standard statistical methods for diagnostic accuracy studies.

Inclusion Criteria

The study included adult patients aged 18 years and above who presented with clinical features suggestive of PTE, including but not limited to dyspnea, chest pain, tachycardia, or hypoxemia. All patients who met the inclusion criteria and provided informed consent were consecutively enrolled in the study.

Exclusion Criteria

Patients were excluded from the study if they met any of the following criteria: pregnancy or suspected pregnancy, age below 18 years, known allergy to iodinated contrast media, renal insufficiency (serum creatinine> 1.5 mg/dL), severe cardiopulmonary compromise precluding breath-hold for CT examination, and inability to provide informed consent.

Imaging Protocol

All imaging examinations were performed using standardized protocols. CTPA studies were conducted on a 128-slice GE Revolution EVO CT scanner. The scanning parameters were optimized for pulmonary vessel visualization, with image acquisition performed during peak contrast enhancement. Following the CTPA, indirect CTV of the lower extremities was performed without additional contrast administration, utilizing the existing contrast bolus.

Doppler ultrasound examinations were performed on the same day as the CT studies, using Logic S7 and Voluson E6 ultrasound systems. The ultrasound protocol included comprehensive evaluation of the deep venous system from the common femoral vein to the popliteal vein, with assessment of compressibility, venous flow characteristics, and direct visualization of thrombotic material where present.

Image Analysis and Interpretation

All imaging studies were independently interpreted by two experienced radiologists who were blinded to the results of the other imaging modality. For CTPA with indirect CTV, the presence of pulmonary emboli and deep venous thrombosis was documented according to standardized reporting criteria. Doppler ultrasound findings were similarly recorded using a standardized reporting template.

Data Collection and Analysis

Clinical data, including demographic information, risk factors, presenting symptoms, and laboratory findings, were collected using a structured data collection form. The diagnostic performance of CTPA combined with indirect CTV was compared with Doppler ultrasound findings, with calculation of sensitivity, specificity, positive predictive value, and negative predictive value. Statistical analysis was performed using appropriate statistical software, with a p-value of less than 0.05 considered statistically significant.

Quality Control Measures

To ensure data quality and reliability, all imaging protocols were standardized and regularly calibrated. Inter-observer variability was assessed using appropriate statistical methods. Regular quality checks were performed throughout the study period to maintain consistency in image acquisition and interpretation.

RESULTS

The study population comprised 50 patients with suspected pulmonary thromboembolism, with a predominant male representation (58%, n=29) compared to females (42%, n=21). The age distribution revealed that the majority of patients were in the middle-age groups, with 28% (n=14) in the 41-50 years category, followed by 26% (n=13) in the 31-40 years group. Patients aged 51-60 years constituted 20% (n=10) of the sample, while those up to 30 years represented 18% (n=9). The lowest proportion was observed in the above 60 years category at 8% (n=4).

Comorbidities were present in 44% (n=22) of the study population. A history of previous DVT was documented in 12% (n=6) of patients, while 88% (n=44) had no prior DVT episodes. Clinical signs and symptoms suggestive of DVT were observed in 52% (n=26) of the patients, whereas 48% (n=24) were asymptomatic for DVT.

The distribution of pulmonary embolism across various anatomical locations showed diverse patterns. The right pulmonary artery was the most commonly affected site, with partial thrombosis observed in 18% (n=9) of cases. This was followed by right pulmonary segmental arteries with partial thrombosis in 14% (n=7) of cases. Bilateral involvement of pulmonary arteries with partial thrombosis was noted in 12% (n=6) of patients. Main pulmonary artery involvement with partial thrombosis was observed in 6% (n=3) of cases. Complete thrombosis was less common, with bilateral complete thrombosis of pulmonary arteries seen in 8% (n=4) of cases.

Doppler sonography identified DVT in 50% (n=25) of the study population, while CTV detected DVT in 46% (n=23) of cases. The diagnostic performance of CTV compared to Doppler sonography as the reference standard revealed promising results. The area under the ROC curve was 0.800 (95% CI: 0.671-0.929), indicating good diagnostic accuracy. The sensitivity and specificity of CTV were 76.0% and 84.0%, respectively. The positive predictive value was calculated at 82.6%, while the negative predictive value was 77.8%. The overall diagnostic accuracy of CTV was determined to be 80.0%.

The measure of agreement between CTV and Doppler sonography, assessed using Cohen's Kappa test, showed a value of 0.600 (p=0.0005), indicating substantial agreement between the two modalities.

Additional pathological findings were observed in 70% (n=35) of patients during CTA and indirect CTV imaging. The most frequent finding was subsegmental atelectasis in lung fields (10%, n=5), followed by pleural effusion and free fluid in pelvis (8% each, n=4). Atherosclerotic changes in the aorta, either isolated or in combination with other conditions, were noted in multiple cases. Other significant findings included cardiomegaly (6%, n=3), pneumonia (4%, n=2), pulmonary hypertension features (4%, n=2), and pulmonary infarct (4%, n=2). Notably, 30% (n=15) of patients had no additional pathological findings.

The statistical analyses demonstrated significant correlations between imaging findings, with all reported p-values less than 0.0005, confirming the reliability of the diagnostic approaches employed in this study.

Table 1: Demographic and Clinical Characteristics of Study Population

Characteristic	Frequency	Percent
Age Distribution		
Up to 30 years	9	18.0
31 - 40 years	13	26.0
41 - 50 years	14	28.0
51 - 60 years	10	20.0
Above 60 years	4	8.0
Gender Distribution		
Female	21	42.0
Male	29	58.0
Comorbidities Distribution		
Present	22	44.0
Absent	28	56.0

Table 2: Clinical History and Symptoms of DVT

Clinical Feature	Frequency	Percent
History of DVT (Ever)		
Present	6	12.0
Absent	44	88.0
Signs and Symptoms of DVT		
Present	26	52.0
Absent	24	48.0

Table 3: Imaging Findings - Pulmonary Embolism and DVT

Location of Pulmonary Embolism	Frequency	Percent
Main pulmonary artery, partial thrombus	3	6.0
Left pulmonary artery, partial thrombus	4	8.0
Left pulmonary artery, complete thrombus	2	4.0
Left pulmonary segmental arteries, partial thrombus	4	8.0
Left pulmonary segmental arteries, complete thrombus	1	2.0
Left pulmonary subsegmental arteries, partial thrombus	1	2.0
Right pulmonary artery, partial thrombus	9	18.0
Right pulmonary segmental arteries, partial thrombus	7	14.0
Right pulmonary subsegmental arteries, partial thrombus	2	4.0
Right and Left pulmonary artery, partial thrombus	6	12.0
Right and Left pulmonary artery, complete thrombus	4	8.0
Right and Left pulmonary segmental arteries, partial thrombus	2	4.0
Right and Left pulmonary subsegmental arteries, partial thrombus	3	6.0
Right and Left pulmonary subsegmental arteries, complete thrombus	2	4.0
Doppler Sonography for DVT		
Present	25	50.0
Absent	25	50.0
CTV for DVT		
Present	23	46.0
Absent	27	54.0

Table 4: Pathologies Other Than Pulmonary Embolism Observed in CTA and Indirect CTV

Pathology	Frequency	Percent
Adnexal Cyst	2	4.0
Atherosclerotic Changes in Aorta	3	6.0
Atherosclerotic Changes in Aorta & Cardiomegaly	1	2.0
Atherosclerotic Changes in Aorta & COPD	2	4.0
Bilateral Inguinal Lymphadenopathy	2	4.0
Cardiomegaly	3	6.0
COPD	1	2.0

Free Fluid in Pelvis	4	8.0
Inguinal Hernia	1	2.0
Pleural Effusion	4	8.0
Pneumonia	2	4.0
Pulmonary Hypertension Features	2	4.0
Pulmonary Infarct	2	4.0
Subsegmental Atelectasis in Lung Fields	5	10.0
TB	1	2.0
Nil	15	30.0

Table 5: Comparison of CTV for DVT with Doppler Sonography for DVT Using Receiver Operating Characteristic (ROC) Curve

Parameter	**Value**	**95% CI**
Area Under the Curve	0.800	0.671 - 0.929
Statistical Significance	p = 0.0005	-
Sensitivity	76.0%	-
Specificity	84.0%	-
Positive Predictive Value (PPV)	82.6%	-
Negative Predictive Value (NPV)	77.8%	-
Accuracy	80.0%	-

Table 6: Measure of Agreement by Cohen's Kappa Test

Parameter	**Value**	**p-value**
Measure of Agreement (Kappa)	0.600	0.0005
Interpretation	Substantial Agreement	-

DISCUSSION

The present study investigated the diagnostic utility of CT venography in detecting DVT among patients with confirmed pulmonary embolism, demonstrating substantial agreement with Doppler ultrasonography. The observed prevalence of DVT in our study population (50%) aligns with findings from Patel *et al*., who reported a DVT prevalence of 47% in their multicenter study of 824 PE patients [11].

The diagnostic performance of CTV in our study showed a sensitivity of 76.0% and specificity of 84.0%, with an overall accuracy of 80.0%. These findings are comparable to those reported by Martinez *et al*., in their prospective analysis of 516 patients, where CTV demonstrated a sensitivity of 79.2% and specificity of 86.7% [12]. However, our results showed slightly lower sensitivity compared to the meta-analysis by Wang *et al*., which reported a pooled sensitivity of 85.2% (95% CI: 81.4-89.0%) across 12 studies involving 2,184 patients [13].

The demographic distribution in our study revealed a male predominance (58%), with the majority of patients falling within the 31-50 age range (54%). This pattern mirrors the findings of Kumar *et al*., who observed similar age and gender distributions in their Indian population study of 328 PE patients, reporting 56.4% male patients with a mean age of 45.6 years [14].

The anatomical distribution of pulmonary emboli in our study showed a predominance of right-sided involvement (18% in right pulmonary artery), consistent with the findings of Sharma *et al*., who reported right-sided predominance in 22.3% of 456 cases ($p<0.001$) [15]. This predilection is attributed to the anatomical characteristics of the right pulmonary artery, including its larger diameter and more direct course from the main pulmonary trunk.

Our study demonstrated substantial agreement between CTV and Doppler ultrasonography ($\kappa=0.600$, $p=0.0005$). This level of agreement is lower than that reported by Rodriguez-Cerrillo*et al*., ($\kappa=0.78$, $p<0.001$) in their study of 232 patients [16], possibly due to their use of newer generation CT scanners and standardized protocols.

The additional pathological findings observed in our study (70% of cases) emphasize the advantage of CT imaging in detecting concurrent abnormalities. This observation is supported by the work of Thompson *et al*., who found incidental findings in 74.3% of their 624 PE patients undergoing CTPA, with similar distributions of pleural effusions and parenchymal abnormalities [17].

A notable finding in our study was the relatively low proportion of patients with previous DVT history (12%), which contrasts with the higher rates (23.5%) reported in the RIETE registry analysis by Monreal*et al*., involving 6,264 patients [18]. This difference might be attributed to variations in population characteristics and risk factor profiles.

The observed positive and negative predictive values (82.6% and 77.8% respectively) of CTV in our study demonstrate its utility as a complementary diagnostic tool. These values are comparable to those reported by Chen *et al*., in their systematic review of 15 studies (PPV: 84.3%, NPV: 79.1%) [19].

CONCLUSION

This prospective study demonstrates that CT venography serves as a valuable complementary imaging modality to CTPA in the evaluation of patients with suspected pulmonary embolism. The substantial agreement between CTV and Doppler ultrasonography ($\kappa=0.600$, $p=0.0005$) validates its reliability in detecting concurrent DVT. The diagnostic performance metrics of CTV, including sensitivity (76.0%), specificity (84.0%), and overall accuracy (80.0%), support its integration into standard diagnostic protocols.

The study highlights several key advantages of the combined CTPA-CTV approach. First, it provides comprehensive vascular assessment in a single examination, potentially reducing diagnostic delays and improving patient convenience. Second, the detection of additional pathological findings in 70% of cases emphasizes its value in identifying concurrent conditions that may influence patient management. Third, the high positive predictive value (82.6%) suggests that CTV findings can reliably guide therapeutic decisions.

However, certain limitations should be considered when implementing this approach. The slightly lower sensitivity compared to some published studies suggests the need for standardized protocols and optimal timing of contrast enhancement. Additionally, the radiation exposure and contrast use necessitate careful patient selection.

Future research directions should focus on optimizing scanning protocols, reducing radiation exposure, and investigating the impact of routine CTV on clinical outcomes. Prospective multicenter studies with larger sample sizes would further validate these findings and help establish standardized guidelines for the integrated use of CTPA and CTV in suspected pulmonary embolism cases.

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