

Original Article



Diagnostic Success of Non-contrast Computed Tomography Findings in Central Acute Pulmonary Thromboembolism: A Case Control Study

 Mutlu Onur Güçsav¹,  Serkan Öner²,  Zeynep Ayvat Öcal²,  Aysu Ayrancı¹,  Damla Serçe Unat³,  Ömer Selim Unat³

¹Department of Pulmonology, Bakırçay University Faculty of Medicine, İzmir, Türkiye

²Department of Radiology, Bakırçay University Faculty of Medicine, İzmir, Türkiye

³Clinic of Pulmonology, University of Health Sciences Türkiye, İzmir Dr. Suat Seren Chest Diseases and Surgery Training and Research Hospital, İzmir, Türkiye

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Abstract

OBJECTIVE: Computed tomography pulmonary angiography (CTPA) is the gold standard in the diagnosis of pulmonary thromboembolism (PTE) but it cannot be used safely in conditions such as renal failure and contrast allergy. Therefore, recognition of emboli with non-contrast thoracic CT can be useful in the management of PTE. The aim of our study was to determine the diagnostic success of non-contrast thoracic CT findings in the diagnosis of PTE.

MATERIAL AND METHODS: Patients who had both non-contrast thorax CT and CTPA imaging within 24 hours and were diagnosed with PTE were analyzed. A control group was formed by randomization in a 1:1 ratio (n = 55). CTPA images of the patients in both groups were evaluated blindly by two expert radiologists and demographic and clinical characteristics were recorded.

RESULTS: Fifty-five patients had embolism. The mean age was 68.5±15.2. Mortality rates were 36.4% in the embolism group and 40.0% in the control group. The main pulmonary artery diameter was significantly higher in the PTE group (32.0 mm vs. 29.4 mm, $P = 0.007$). The mean attenuation of the pulmonary blood pool in the PTE group was higher than that of the control group [46.2 Hounsfield units (HU) (29.4-63.9) vs. 41.1 HU (32.5-62.4)] ($P = 0.025$).

CONCLUSION: Direct and indirect findings obtained from non-contrast thoracic CT can help the diagnosis, in patients in whom CTPA cannot be performed. Diagnostic utility may increase when the presence of these findings is evaluated together with clinical and laboratory findings. Validation studies should be performed in larger populations.

KEYWORDS: Non-contrast computed tomography, pulmonary thromboembolism, diagnosis, pulmonary artery

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INTRODUCTION

Pulmonary thromboembolism (PTE) is a disease that occurs when the pulmonary arteries (PA) and their branches are occluded by fragments of thrombi from various veins. It usually occurs together with deep vein thrombosis. The two are called venous thromboembolism.¹ It is the third most common acute cardiovascular syndrome after myocardial infarction and stroke.² In epidemiological studies, the annual incidence of PTE varies between 39 and 115 per 100,000 population.^{1,3} Mortality rates of up to 30% are observed in untreated patients.⁴ Early diagnosis is particularly important to prevent mortality and morbidity.

The widespread use of non-invasive imaging methods and increased awareness of PTE have led to an increase in its incidence. Computed tomography pulmonary angiography (CTPA) is the gold standard imaging modality in patients with suspected PTE. Thanks to its multi-detector scanners, the medical imaging system can reliably detect emboli

Corresponding author: Damla Serçe Unat MD, e-mail: sercedamla@gmail.com

even at the subsegmental level.⁴⁻⁶ It has been shown that as the number of sections increases, the diagnostic success increases in segmental and subsegmental embolism.^{7,8} CTPA also allows simultaneous assessment of other structures, such as the mediastinum, lung parenchyma, and aorta (Ao).⁴

Although CTPA is a gold standard method in diagnosis, it cannot be used safely in conditions such as renal failure, contrast allergy, pregnancy, and breastfeeding.⁹ Due to the excessive cost of the device, CTPA is not accessible in many centers. In addition, renal function tests have to be completed before CTPA, which delays the diagnosis of the disease. Therefore, in recent years, researchers have started to research the recognition of emboli, especially in the proximal branches of the PA. They have used non-contrast thoracic CT. These studies often focus on the hyperdense lumen finding observed in the area where the embolus is located.^{4,5,10,11} However, the incidence of hyperdense lumen finding is approximately 35%.¹⁰ In addition to this finding, measuring the mean attenuation of the pulmonary blood pool the diameters of the PAs and their branches, and detecting indirect signs of PTE may help in the early diagnosis of acute PTE in patients who cannot use contrast agents.

The aim of our study was to determine the diagnostic success of non-contrast thorax CT findings for PTE using CTPA as the gold standard.

MATERIAL AND METHODS

Study Population

Our study was planned as a retrospective case-control study. The study was approved by the Ethics Committee of the İzmir Bakırçay University on the 5th of January 2022 (decision no: 478). Patients aged 18-80 years who applied to the emergency department of a tertiary hospital between January 2016 and December 2021 and had both non-contrast thoracic CT and CTPA imaging within 24 hours were analyzed. The rationale for performing two CT scans within a 24-hour period was that, in most cases, an initial non-contrast thoracic CT was performed in the emergency department to assess non-specific

symptoms such as chest pain, dyspnea, or hemoptysis. This scan served as a general screening tool to evaluate alternative thoracic pathologies. When PTE was subsequently suspected based on clinical evolution and pulmonology consultation, CTPA was performed within the same 24-hour interval. Patients with segmental and subsegmental embolism, pulmonary hypertension (HT), chronic PTE, inadequate contrast enhancement preventing CTPA evaluation, hemoglobin (Hb) levels <7 g/dL, and data loss were excluded from the study. A total of 47 patients met these exclusion criteria. CTPA reports of the remaining eligible patients were then analyzed. CTPA images of the patients were evaluated blindly by two expert radiologists working in our hospital and the diagnoses were confirmed. The case group included patients with thromboembolism involving the main, right or left PAs, or lobar branches (n = 55). Among the control population, CT scans of 529 patients were independently reviewed in a double-blinded manner by two radiologists. Patients with additional radiologic abnormalities that could potentially confound vascular assessment were excluded, including those with vascular anomalies (n = 5), PA-invasive masses (n = 11), and congenital cardiac anomalies (n = 1). After these exclusions, 512 patients remained eligible. To achieve a 1:1 ratio with the case group, 55 control patients were selected from this cohort using systematic random sampling.

Demographic data, comorbid diseases, laboratory, non-contrast CT findings, echocardiography findings, and outcome status of all patients in the case and control groups were documented. The groups were compared in terms of these variables, especially non-contrast CT findings, and the data were analyzed (Figure 1).

Main Points

- Diagnosing pulmonary embolism (PTE) can be challenging due to its non-specific clinical presentation.
- Computed tomography pulmonary angiography (CTPA) is the gold standard for PTE diagnosis, but it may not be feasible in patients with contrast allergy or renal impairment.
- In this study, patients who underwent non-contrast thoracic CT followed by CTPA within 24 hours were retrospectively compared with a control group that had only non-contrast thoracic CT.
- Pulmonary artery enlargement and increased attenuation in the pulmonary blood pool on non-contrast thoracic CT are notable indicators of PTE.
- In cases where CTPA is not possible, non-contrast thoracic CT findings, when evaluated alongside clinical and laboratory data, may enhance diagnostic accuracy.

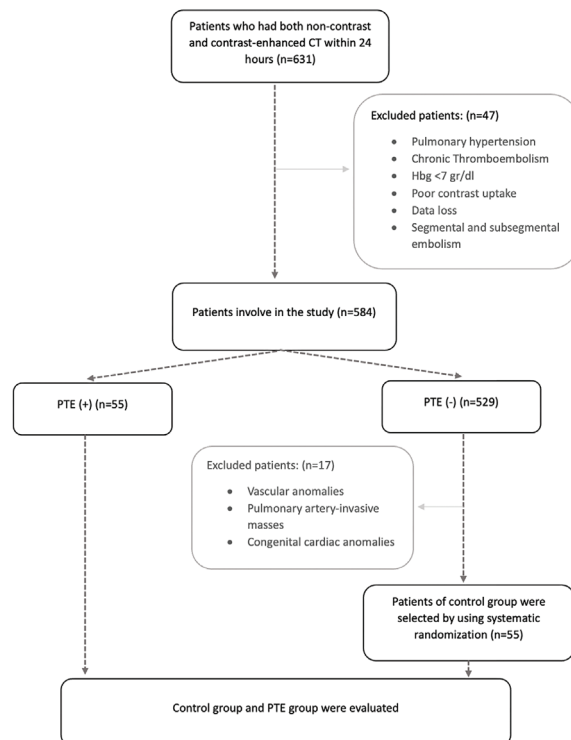


Figure 1. Patient selection and study design of research

CT: computed tomograph, Hbg: hemoglobin, PTE: pulmonary thromboembolism

Computed Tomography Protocol

Non-contrast thoracic CT and CTPA were performed in all patients using a 128-detector spiral CT scanner (GE Optima CT660®, USA). In CTPA, 50 mL of contrast material (iohexol) was administered intravenously through the antecubital vein as a bolus injection, followed by a saline chaser at a rate of 4.5 mL/sec. Image acquisition was performed in the PA phase. On non-contrast thoracic CT, images were reconstructed with a slice thickness of 3 mm, whereas the axial images from CTPA were reconstructed with a slice thickness of 0.625 mm. All images were interpreted on a standard PACS workstation by two experienced radiologists blinded to the clinical data. The evaluations were performed blindly by two experienced radiologists at the hospital workstation. For cardio-vascular diameter and density measurements, mediastinal window settings were used [window width: 350 Hounsfield units (HU); window level: 40 HU], while lung parenchymal findings and indirect signs (e.g., pleural effusion, consolidation, and wedge-shaped opacity) were evaluated using lung window settings (window width: 1500 HU; window level: -600 HU). On non-contrast CT, the diameters of the main PA and ascending Ao were measured at the level of the bifurcation in axial sections, and the PA-to-Ao ratio was calculated. The diameters of the

right main PA and the left main PA were measured at the widest point. For attenuation measurements, four circular regions of interest (ROIs), each measuring 1-1.5 mm², were placed in the main PA, right main PA, and left main PA, making a total of 12 ROIs (Figure 2). Additionally, one ROI was placed in each of the three right lobar arteries and in each of the two left lobar arteries (5 ROIs in total). This resulted in a total of 17 pulmonary vascular locations for density evaluation. All attenuation values were recorded in HU. Pleural and parenchymal changes, and cardiomegaly findings on CT were also noted (Figure 3).

Statistical Analysis

Statistical analysis was performed using IBM SPSS for Windows® 26.0 software (IBM Corp., Armonk, NY, USA). Demographic data, comorbid diseases, and laboratory findings were presented as descriptive statistics. In descriptive statistics, categorical variables were expressed as numbers and frequency. Continuous variables were presented as mean±standard deviation.

Intraclass correlation analysis was used to measure the agreement between the evaluators in terms of continuous variables when evaluating non-contrast CT. A two-way

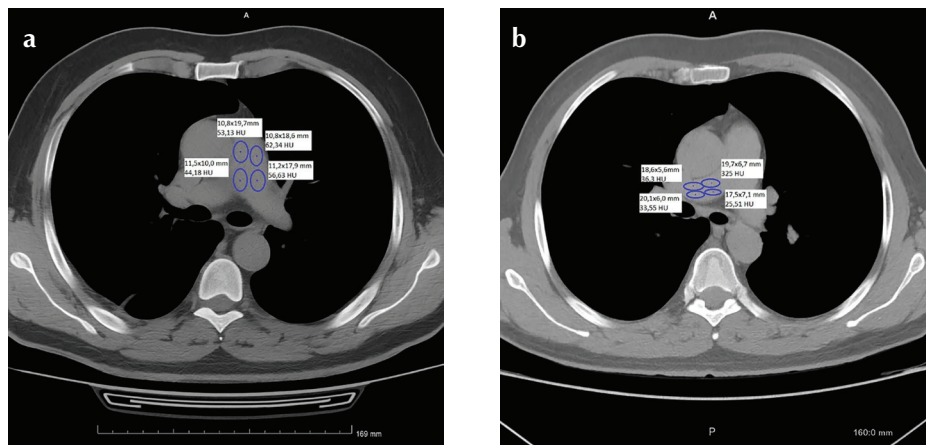


Figure 2. Pulmonary truncus on axial non-contrast thoracic CT image (a) and density measurement with four ROIs placed in the right main pulmonary artery (b)

CT: computed tomography, ROI: regions of interest

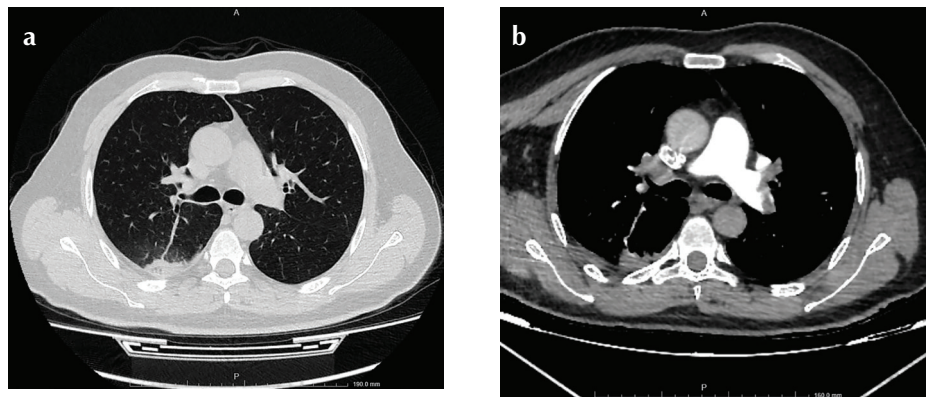


Figure 3. Subpleural consolidation in the right upper lobe posterior segment that suggests pulmonary infarct is shown in axial CT image (a) CTPA image of the same patient, near complete occlusion of the right upper lobe artery (b)

CT: computed tomography, CTPA: computed tomography pulmonary angiography

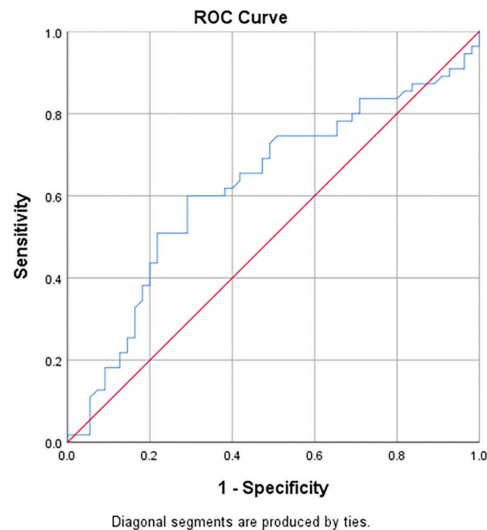


Figure 4. ROC curve for pulmonary blood pool mean attenuation

ROC: receiver operating characteristic

random model was used for these calculations. Agreement in categorical variables was measured by Cohen's Kappa analysis. The agreement between the two reviewers was good for the mean attenuation measurements of the PA pool ($P = 0.850$). This agreement was also good for ascending Ao main PA right main PA, and left main PA diameters. Moderate agreement was obtained in the evaluation of parenchymal findings (Table 1). Because of the good agreement between the reviewers, the data of the more experienced reviewer was used as the basis for statistical analysis.

Before comparing the two groups, the continuous data were analyzed with the Kolmogorov-Smirnov test to determine whether they conformed to the normal distribution. Independent t-test analysis was used for the comparison of data conforming to a normal distribution. Mann-Whitney U analysis was used for the comparison of data not conforming to normal distribution. Chi-square analysis was used to compare categorical variables. $P < 0.05$ was considered statistically significant.

RESULTS

Prevalence and Distribution of Pulmonary Embolism

A total of 631 patients underwent both non-contrast thoracic CT and CTPA within 24 hours of admission. After applying the inclusion and exclusion criteria, 584 patients were deemed eligible for the study. Among these, 55 patients (9.4%) were diagnosed with PTE based on the presence of contrast-filling defects in the main PA and/or lobar branches. Saddle emboli involving the main PA were identified in 10 patients (18.2%), whereas 31 patients (56.3%) had emboli located in the right or left main PAs. In 14 patients (25.5%), emboli were confined to lobar branches. Most emboli were bilateral (70.9%).

Demographic and Clinical Characteristics

The mean age of the study population was 68.5 ± 15.2 years, with no statistically significant difference between the PTE and control groups. Among all patients, 64 were women and 46 were men. The proportion of female patients was significantly

higher in the PTE group ($P = 0.02$). HT was the most common comorbidity observed in both groups, followed by diabetes mellitus and chronic obstructive pulmonary disease. However, HT and malignancy were significantly more prevalent in patients with PTE ($P = 0.008$ and $P = 0.028$, respectively). Troponin and D-dimer levels were also significantly higher in the PTE group ($P < 0.001$), whereas other laboratory parameters did not differ significantly. The overall in-hospital mortality rate was 38.2%, with 36.4% in the PTE group and 40.0% in the control group ($P > 0.05$). Further demographic and clinical data are summarized in Table 2.

Quantitative Vascular and Indirect Signs on Non-contrast Computed Tomography

Quantitative assessment of vascular structures showed that the main PA diameter was significantly higher in the PTE group compared to the control group (32.0 mm vs. 29.4 mm, $P = 0.007$). Similarly, the right PA diameter and the PA-to-Ao ratio were significantly greater in the PTE group ($P = 0.025$ and $P = 0.004$, respectively). In contrast, the left PA diameter showed only borderline significance ($P = 0.053$), and the diameter of the ascending Ao did not differ between groups ($P = 1.00$).

The mean attenuation of the pulmonary blood pool was significantly higher in the PTE group (46.2 HU; range: 29.4-63.9) compared to the control group (41.1 HU; range: 32.5-62.4), ($P = 0.025$). Receiver operating characteristic (ROC) curve analysis identified a threshold of 42.2 HU for predicting the presence of embolism, with a sensitivity of 61.8%, an area under the curve (AUC) of 0.623 [95% confidence interval (CI): 0.51-0.73], and statistical significance ($P = 0.026$). Additional attenuation and diameter measurements are presented in Table 3.

Indirect signs of PTE were present in 65.4% of patients in the embolism group and in 61.8% of those in the control group. Cardiomegaly was the most frequent indirect finding in the PTE group (47.3%), while pleural effusion was more common in the control group (25.5%). Statistically significant differences

Table 1. Inter-rater agreement in non-contrast thoracic CT

Variable	P	95% CI
Ascending aorta diameter	0.873	0.787-0.921
Main pulmonary artery diameter	0.814	0.740-0.869
Right main pulmonary artery diameter	0.845	0.782-0.891
Left main pulmonary artery diameter	0.834	0.767-0.883
Pulmonary blood pool attenuation	0.850	0.785-0.896
Indirect PTE findings*	0.417	0.250-0.584

*: Cohen's Kappa analysis was used, PTE: pulmonary thromboembolism, CI: confidence interval, CT: computed tomography

Table 2. Descriptive statistics and comparison of statistics between groups

	Total (n = 110)	PTE (+) (n = 55)	PTE (-) (n = 55)	P
Age (mean±SD) [‡]	68.5±15.2	70.27±16.81	65.63±13.55	0.07
Gender* (n, %)				0.020
Female	64 (58.2)	38 (69.1)	26 (47.3)	
Male	46 (41.8)	17 (30.9)	29 (52.7)	
Laboratory[‡] (mean±SD)				
Hemoglobin (g/dL)	12.37±1.82	12.32±1.82	12.42±1.85	0.78
Platelets (/uL)	257536±99110	266873±100396	248200±97830	0.33
D-dimer (ng/mL)	3303.00±1382.59	3912±970	2740±1473	<0.001
Troponin (ng/L)	55.34±78.16	80.2±92.5	30.0±49.3	0.001
Comorbidities* (n, %)				
Coronary artery disease	22 (20%)	13 (23.6%)	9 (16.3%)	0.34
Diabetes mellitus	32 (29.1%)	17 (30.9%)	15 (27.2%)	0.63
Interstitial lung disease	0 (0%)	0 (0%)	0 (0%)	1.000
COPD	23 (20.9%)	10 (18.1%)	13 (23.6%)	0.41
Cerebrovascular disease	6 (5.5%)	4 (7.2%)	2 (3.6%)	0.40
Malignancy	8 (7.3%)	7 (12.7%)	1 (1.8%)	0.028
Heart failure	12 (10.9%)	8 (14.5%)	4 (7.3%)	0.22
Hypertension	56 (50.9%)	35 (63.6%)	21 (38.2%)	0.008
Other diseases	36 (32.7%)	16 (29.1%)	20 (36.4%)	0.42
Location of PTE		n = 55		
Saddle		10 (18.2)		
Left and right main pulmonary artery		31 (56.3)		
Lobar		14 (25.5)		

[‡]: independent sample t-test, *: chi-square test, COPD: chronic obstructive lung disease, SD: standard deviation

were observed between the groups in terms of cardiomegaly ($P = 0.010$) and peripheral consolidation or ground-glass opacities ($P = 0.001$). A detailed comparison of indirect findings is provided in Table 4.

Multivariate Analysis of Diagnostic Predictors

Binary logistic regression analysis was performed using the following independent variables: mean HU of the pulmonary blood pool, main PA diameter, right PA diameter, PA/Ao ratio, presence of indirect signs on thorax CT, and D-dimer levels. Prior to the analysis, an outlier assessment was conducted, and

no significant outliers were identified. The model demonstrated an overall prediction accuracy of 73% in distinguishing between case and control groups. According to the analysis, the PA/Ao ratio [$P = 0.034$, odds ratio (OR): 4.886, 95% CI: 1.124-21.240] and D-dimer level ($P < 0.001$, OR: 1.001, 95% CI: 1.000-1.001) were found to be statistically significant independent predictors of PTE. Other variables—including main and right PA diameter, mean HU values, and the presence of indirect signs on non-contrast thoracic CT—did not show a statistically significant contribution to the model ($P > 0.05$ for all) (Table 5).

Table 3. Comparison of non-contrast CT measurements between groups

Variables (mean±SD)	PTE (+) (n = 55)	PTE (-) (n = 55)	P
Diameters (mm)			
Main pulmonary artery	32.04±4.49	29.47±5.20	0.007
Ascending aorta	35.98±4.05	35.98±4.56	1.000
PA/Ao ratio	0.897±0.128	0.824±0.132	0.004
Left main pulmonary artery*	26.00 (19-35)	25.00 (17-30)	0.05
Right main pulmonary artery	25.95±3.71	24.35±3.69	0.025
PA/Ao ratio categorized (n, %)			
Normal (≤0.9)	27 (49.1%)	39 (70.9%)	0.020
High (>0.9)	28 (50.9%)	16 (29.1%)	
Attenuation (HU)			
Mean pulmonary blood pool *	46.2 (29.4-63.9)	41.1 (32.5-62.4)	0.025
Main pulmonary artery	43.70±8.26	43.42±8.66	0.09
Right pulmonary artery	44.13±8.72	43.71±9.40	0.08
Left pulmonary artery*	43.00 (28.2-83.2)	41.75 (28.5-63.2)	0.28

*: Mann-Whitney U test was applied to variables that did not fit the normal distribution. Data are presented as median (min-max), PA/Ao: pulmonary artery diameter/ascenden aort diamater, SD: standard deviation, PTE: pulmonary thromboembolism, CT: computed tomography, HU: Hounsfield units

Table 4. Comparison of indirect signs on non-contrast thoracic CT between groups

Indirect findings	PE (+) (n = 55)	PE (-) (n = 55)	P
Atelectasis	12 (21.8)	7 (12.7)	0.22
Pleural effusion	13 (23.6)	14 (25.5)	0.83
Peripheral consolidation/ground glass	22 (40)	7 (12.7)	0.001
Cardiomegaly	26 (47.3)	13 (23.6)	0.01
Fibrotic bands	1 (1.8)	5 (9.1)	0.09
Mosaic attenuation	2 (3.6)	1 (1.8)	0.56
Others	4 (7.3)	4 (7.3)	1.000

PTE: pulmonary thromboembolism, CT: computed tomography

Table 5. Binary logistic regression analysis results

Variable	OR	95% CI	P
Main pulmonary artery diameter	0.951	0.791-1.143	0.591
Right pulmonary artery diameter	1.091	0.912-1.304	0.342
PA/Ao (categorized)	4.886	1.124-21.240	0.034
Mean pulmonary blood pool HU	1.051	0.983-1.123	0.146
Indirect signs on thoracic CT	2.216	0.696-7.058	0.178
D-Dimer (ng/mL)	1.001	1.000-1.001	<0.001

PA/Ao: pulmonary artery diameter/ascenden aort diamater, CT: computer tomography, CI: confidence interval, HU: Hounsfield units, OR: odds ratio

DISCUSSION

In this retrospective case-control study, we investigated the diagnostic utility of non-contrast thoracic CT findings in detecting central PTE, using CTPA as the reference standard. Our analysis demonstrated that patients with confirmed PTE, had significantly larger main and right PA diameters, higher PA/Ao ratio, and greater mean attenuation values in the pulmonary blood pool compared to control subjects. Additionally, certain indirect signs—such as cardiomegaly and peripheral consolidation/ground-glass opacities—were more frequently observed in the PTE group. In multivariate analysis, PA/Ao ratio and D-dimer levels emerged as independent predictors of PTE, while other imaging markers did not retain statistical significance. These findings suggest that selected non-contrast CT parameters, when interpreted alongside laboratory data, may assist in the diagnosis of central PTE, particularly, in patients for whom CTPA is contraindicated.

Previous studies on this subject show that the hyperdense lumen sign may help the diagnosis in the presence of central PTE.^{4,10,11} However, the small number of cases presented in these studies and insufficient validation studies reduce the reliability.^{11,12} In studies, the diagnostic value of the sign is lost as we move towards segmental and subsegmental branches.¹⁰ In contrast to these studies, Cobelli et al.¹² reported that in some cases of central PTE, hypoattenuation findings may be observed alongside the hyperattenuation sign.

Studies have shown that high attenuation values in the blood pool are caused by an excess of protein in the concentrated red blood cells. As the water content of the thrombus decreases over time, Hb becomes more concentrated, and attenuation values increase.¹³ This suggests that increased thrombus burden, and/or a period after the event, may be required for the appearance of hyperdense lumen sign on non-contrast thoracic CT. In addition, slowing of pulmonary blood flow after PTE has also been reported to cause increased attenuation. The fact that the hyperdense lumen finding occurs after the thrombus is organized, and is observed at low rates in the acute period led us to investigate the diagnostic success of findings, other than hyperdense lumen, on non-contrast thoracic CT. In our study, increased mean pulmonary blood pool attenuation was associated with PTE.¹⁰ Our data suggest that increased attenuation of the pulmonary blood pool caused by slowed pulmonary blood flow after thrombus may be another diagnostic finding in addition to hyperdense lumen sign.

The mean attenuation in the pulmonary blood pool outside the embolus area was 36.3 HU in the study by Kanne et al.¹¹ and 38.3 HU in the study by Tatco and Piedad.¹⁰ In these studies, the attenuation of embolism areas varied between 60-65 HU.^{10,11} In our study, the predictive value for the mean attenuation of the pulmonary blood pool including the embolus areas was found to be 42.2 HU.

Although ROC curve analysis demonstrated that increased mean pulmonary blood pool attenuation was significantly associated with the presence of pulmonary embolism, the AUC value of 0.623 indicates only modest diagnostic performance. This relatively low AUC suggests that blood pool attenuation alone may not be sufficient for reliable diagnosis and should

not be used in isolation. Instead, it should be interpreted in conjunction with other imaging features (e.g., PA/Ao ratio, parenchymal findings) and clinical parameters. Our findings emphasize that while pulmonary blood pool attenuation may serve as a supportive radiological clue, its diagnostic utility is limited, and should be further validated through larger studies with more robust predictive modeling.

Truong et al.¹⁴ found a main PA diameter of 25.1 ± 2.8 mm in the normal population; a cut-off value of 28.9 mm in men and 26.9 mm in women was associated with dyspnea. The PA/Ao ratio was reported as 0.77 ± 0.09 in that same cohort.¹⁴ In the study by Edwards et al.¹⁵, the mean diameter of the main PA was measured as 27.2 ± 3.0 mm, with the upper limit defined at 33.2 mm. Based on these and similar studies, an upper reference value of 29 mm for main PA diameter and a PA/Ao ratio of 0.9-1 is generally accepted as thresholds in thoracic CT evaluation. In a separate comparative study between acute PTE patients and healthy individuals, significantly increased values for main, left, and right PA diameters, and PA/Ao ratios were found in the PTE group.¹⁶ Consistent with these data, our study also demonstrated that increased PA diameter and elevated PA/Ao ratio were significantly associated with PTE. These findings suggest that measurement of PA diameters and PA/Ao ratio on non-contrast thoracic CT may serve as valuable indicators in patients with suspected PTE, particularly in those without known conditions that elevate PA pressure.

Studies have shown that indirect parenchymal findings may guide in the diagnosis of PTE. In the study by Coche et al.¹⁸, pleural-based consolidations and fibrotic band findings were found to be associated with PTE. Only wedge-shaped consolidation was found to be associated with PTE in the Pfeil et al.¹⁷ study. In our study, the presence of parenchymal consolidation/ground-glass and cardiomegaly was found to be associated with PTE. The finding of peripheral consolidation/ground glass and cardiomegaly on non-contrast thoracic CT may indicate the need for further investigation for PTE.

The interpretation of non-contrast thoracic CT findings may be influenced by several potential confounding factors. One of the most important factors is the patient's Hb level at the time of imaging, which directly affects blood attenuation values on CT scans. Higher Hb levels are associated with increased attenuation, independent of the presence of thrombus, potentially mimicking the hyperdense lumen sign or elevating mean blood pool HU values.¹³ Furthermore, cardiopulmonary conditions such as chronic pulmonary HT, left heart failure, or fluid overload can lead to vascular remodeling or enlargement, thereby influencing PA diameters and the PA/Ao ratio.¹⁴ Additionally, concurrent pulmonary infections, neoplastic processes, or interstitial lung diseases may produce parenchymal changes (e.g., ground-glass opacities or consolidations) that mimic or obscure indirect signs of PTE.¹⁸ In our study, although patients with known confounding conditions such as chronic thromboembolism, PA-invasive masses, or severe anemia (Hb <7 g/dL) were excluded, the presence of unrecorded or subclinical factors cannot be ruled out entirely. This limitation underscores the need for comprehensive clinical correlation and, ideally, prospective studies that can better control for such confounding variables.

In the multivariate logistic regression analysis, only the PA/Ao ratio and D-dimer levels emerged as statistically significant independent predictors of PTE. The PA/Ao ratio was strongly associated with the presence of PTE, with a remarkably high OR, although the wide CI suggests a degree of imprecision, likely due to the limited sample size. Similarly, elevated D-dimer levels were independently associated with PTE, consistent with their established role in thromboembolic risk stratification. Other imaging parameters, including mean HU values of the pulmonary blood pool, main PA diameter, and the presence of indirect signs on non-contrast thoracic CT, did not retain statistical significance in the multivariate model. These findings imply that while certain non-contrast thoracic CT features may appear relevant in univariate analyses, their predictive utility may diminish when adjusted for other factors. This underscores the importance of combining radiologic indicators with laboratory and clinical data to enhance diagnostic accuracy.

In our study, agreement between radiologists was good in terms of attenuation and diameter measurements. Agreement rates decreased when lobar branches were included in the analysis. Our data show that higher agreement rates were achieved than in similar studies in the literature.^{4,10}

This study has several limitations that should be acknowledged. First, the relatively small sample size ($n = 110$) may limit the statistical power and generalizability of the findings. Second, the single-center design may introduce selection bias and limit the applicability of the results to broader clinical settings. Due to the retrospective nature of the analysis, complete clinical parameters and standardized risk scores (e.g., Wells, Geneva) were not consistently recorded, precluding their integration into the analysis. We acknowledge that integrating imaging findings with established clinical scoring systems such as the Wells or Geneva criteria could potentially enhance the diagnostic accuracy and clinical applicability of our results. However, due to the retrospective design of our study and the absence of complete clinical data required to calculate these scores, such an analysis could not be performed. Future prospective studies that include standardized clinical probability assessments in conjunction with imaging parameters may better elucidate the complementary role of non-contrast thoracic CT findings in the diagnostic algorithm of pulmonary embolism.

CONCLUSION

Non-contrast thoracic CT provides valuable direct and indirect radiological markers that may aid in the diagnosis of PTE, particularly in settings where CTPA is contraindicated or unavailable, such as in patients at risk for contrast-induced nephropathy. Our findings demonstrate that increased PA diameters, elevated PA/Ao ratios, and higher attenuation values of the pulmonary blood pool are significantly associated with the presence of PTE. Additionally, the presence of indirect findings further supports the radiological suspicion of embolism.

Diagnostic success may increase when the presence of these findings is evaluated together with clinical and laboratory findings. Validation studies to be performed in a larger population are needed for the findings to be used in the clinic,

obtained in our study.

Ethics

Ethics Committee Approval: The study was approved by the Ethics Committee of the İzmir Bakırçay University on the 5th of January 2022 (decision no: 478).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Concept: M.O.G., A.A., Ö.S.U., Design: M.O.G., S.Ö., D.S.U., Data Collection or Processing: Z.A.Ö., A.A., D.S.U., Analysis or Interpretation: M.O.G., Z.A.Ö., Ö.S.U., Literature Search: M.O.G., S.Ö., Writing: M.O.G., Z.A.Ö., D.S.U.

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