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Diagnostic Accuracy of Non-Contrast Chest CT in Detecting Pulmonary Thromboembolism: A Retrospective Analytical Study

Khemendra Kumar[1]*, Arpana Agrawal[2], Vagisha Dahiya[2], Rupanshi Jain[2]
**Corresponding Author; Email: drkhem@gmail.com*
[1] (*Associate Professor, Department of Radiodiagnosis, School of Medical Sciences & Research, Sharda University, Greater Noida, India)*
[2] *(Junior resident, Department of Radiodiagnosis, School of Medical Sciences & Research, Sharda University, Greater Noida, India)*

Abstract
Background: *Pulmonary thromboembolism (PTE) is a potentially life-threatening condition with nonspecific clinical presentation. While CT Pulmonary Angiography (CTPA) is the diagnostic gold standard, non-contrast computed tomography (NCCT) chest scans may offer valuable insights, particularly in patients who cannot receive contrast.*
Objective: *To evaluate the diagnostic accuracy of NCCT chest scans for evaluation of PTE, focusing on hyperdense lumen sign, average HU (Hounsfield) of pulmonary arteries, pulmonary artery diameter measurements, right atrium and right ventricle dilatation. These findings were compared to CTPA.*
Methods: *This retrospective analytical study included 66 patients who underwent both NCCT and CTPA between 2016 and 2023. Hyperdense lumen sign, average HU (Hounsfield) of pulmonary arteries, pulmonary artery diameter measurements, right atrium and right ventricle dilatation were evaluated on NCCT and compared with CTPA results. Statistical analyses included t-tests, chi-square tests, and ROC curve analysis.*
Results: *Hyperdense lumen sign was significantly associated with pulmonary thromboembolism detected on CTPA. Other findings like average HU (Hounsfield) of pulmonary arteries, pulmonary artery diameter measurements, right atrium and right ventricle dilatation were not significantly associated with pulmonary thromboembolism.*
Conclusion: *NCCT may serve as a useful adjunct in detecting pulmonary thromboembolism in clinically unsuspected cases and warrant further evaluation with CTPA if hyperdense lumen sign is positive.*

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I. Introduction

The clinical appearance of pulmonary embolism, a potentially lethal condition, may be silent.(1) Many times, it may even go undiscovered because, according to autopsy data, the true number of cases is likely three times higher and that many individuals pass away before the diagnosis is even made.(2) In the general community, there are roughly 3-6 incidences of acute pulmonary embolism (PE) per 10,000 people each year.(3,4) With no prior history of pulmonary or cardiac disease, dyspnea, chest discomfort, or tachypnea are the primary symptoms in around 97% of patients.(2)

Further evaluation is necessary because the diagnosis of pulmonary embolism cannot be ruled out only through clinical evaluation or suspicion [5]. The initial established imaging method for the diagnosis of pulmonary emboli is CT Pulmonary Angiography (CTPA) at many institutions. (6) The usefulness of non-contrast CT chest in pulmonary embolism identification based on the diagnosis of high attenuation thrombi in the pulmonary arteries has only been the subject of a small number of studies. [7]. Additionally, incorporating an unenhanced study into the CT Pulmonary Angiography protocol is beneficial for a number of other purposes, such as assessing the lung parenchyma and chest wall and locating any calcified lesions. Ancillary findings in the chest scans like presence of wedge shaped hyperdensity and pleural effusion can also be studied. [8].

In contrast to distal pulmonary embolism and chronic pulmonary embolism, acute central pulmonary embolism is linked with serious hemodynamic alterations and a greater mortality rate, making prompt intervention essential for successful treatment [7]. In cases where CT Pulmonary Angiography cannot be conducted or is not available, the radiologists' capacity to make an accurate diagnosis of pulmonary embolism based on Multi Detector CT data may be helpful. (6)

Hassan et al. (2021) concluded that NCCT chest imaging could reliably predict central and peripheral PE, particularly in patients unable to undergo CTPA.[9] Chien et al. (2019) reported a sensitivity of 96.9% and specificity of 71.9% for NCCT when positive findings were present, including hyperdense thrombi, main pulmonary artery (MPA) dilatation greater than 33.2 mm, and peripheral wedge-shaped consolidations[6]. Kaykisiz et al. (2018) emphasized the value of identifying the 'hyperdense lumen sign' on NCCT, even in patients without clinical suspicion of PE[12]. Thom et al. (2017) presented cases where NCCT was instrumental in diagnosing central PE in emergency settings where contrast use was contraindicated[11]. Tatco et al. (2011) found that hyperdense thrombi on NCCT had a specificity of 99%, though sensitivity remained low at 36%.[10]

Given the significant hemodynamic impact and mortality associated with central PE, prompt diagnosis and intervention are critical. This study evaluates the diagnostic performance of NCCT chest imaging in detecting pulmonary thromboembolism, with CTPA serving as the reference standard.

II. Materials and Methods

This retrospective analytical study was conducted in the Department of Radiology, School of Medical Science and Research, Greater Noida, Uttar Pradesh, India. The study was approved by the Institutional Ethics Committee (IEC), which also granted a waiver of informed consent due to the retrospective nature of the research.

The study included patients who underwent both NCCT chest scans and CT Pulmonary Angiography (CTPA) between 2016 and 2023 at Sharda Hospital, Greater Noida. A total of 66 patients met the inclusion criteria and were evaluated.

Inclusion criteria comprised all patients who underwent both NCCT and CTPA imaging during the study period. Exclusion criteria included suboptimal image quality, poor contrast opacification on CTPA precluding evaluation, and incomplete clinical or imaging records.

NCCT chest scans were initially performed prior to contrast administration for CTPA. All imaging studies were retrieved from the hospital Picture Archiving and Communication System (PACS). NCCT and CTPA scans were independently reviewed by two radiologists: a radiology resident with a minimum of two years of experience and a senior faculty radiologist with over ten years of experience. Discrepancies in interpretation were resolved by consensus.

On NCCT, intraluminal hyperdensity (hyperdense lumen sign) was assessed in the main pulmonary artery (MPA), right pulmonary artery (RPA), and left pulmonary artery (LPA). Hounsfield Unit (HU) values measured at three locations in each artery and averaged. Subjective assessment of hyperdense lumen sign was made independently by a radiologist with more than 10 years of experience on the NCCT images. The diameter of the MPA was measured at the level of bifurcation on axial images, with dilatation defined as a diameter of 30 mm or greater. Right atrial dilatation was evaluated by calculating the ratio of the right atrium (RA) to the left atrium (LA). Similarly, right ventricular dilatation was assessed by measuring the ratio of the right ventricle (RV) to the left ventricle (LV) diameters. A ratio equal to or greater than 1 was considered abnormal, indicating dilatation of the RA and RV, respectively.[13,14]

CTPA served as the reference standard for diagnosing pulmonary thromboembolism. The presence of pulmonary thromboembolism was specifically compared to corresponding findings on NCCT. A total of 66 patients was included based on available imaging records from 2016 to 2023, who underwent NCCT chest and CT pulmonary angiography.

The data was compiled and analyzed using Microsoft Excel and SPSS version 21.0. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were summarized as frequencies and percentages. The primary objective of the statistical analysis was to evaluate the diagnostic performance of four key parameters identified on non-contrast computed tomography (NCCT) chest scans in the detection of pulmonary thromboembolism (PTE), using CT Pulmonary Angiography (CTPA) as the gold standard reference.

The association between each NCCT parameter and thrombus detection on CTPA was analyzed using the Chi-square test for categorical variables. A p-value less than 0.05 was considered to indicate statistical significance. For each of the four parameters, diagnostic accuracy was determined by calculating sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV).
Receiver operating characteristic (ROC) curve analysis was conducted to evaluate the diagnostic performance of the NCCT parameters in predicting pulmonary thromboembolism.

III. Results

A total of 66 patients were included in the study. Pulmonary thromboembolism (PTE) was confirmed on CT Pulmonary Angiography (CTPA) in 14 patients (21.2%), while 52 patients (78.8%) did not demonstrate thrombus on CTPA.

The hyperdense lumen sign on non-contrast computed tomography (NCCT) was observed in 10 patients. Of these, 9 had thrombus confirmed on CTPA, while 1 case was negative for thrombus. Among the 56 patients without the hyperdense lumen sign, 5 had thrombus on CTPA and 51 were negative. The chi-square test demonstrated a highly significant association between the presence of a hyperdense lumen sign on NCCT and thrombus on CTPA ($p < 0.0001$).

The diagnostic performance of the hyperdense lumen sign was notable, with a sensitivity of 64%, specificity of 98%, positive predictive value (PPV) of 90%, and negative predictive value (NPV) of 91%. The area under the ROC curve (AUC) for the hyperdense lumen sign was 0.81, indicating good discriminative ability.

Main Pulmonary Artery (MPA) dilatation, defined as a diameter ≥ 30 mm, was noted in 29 patients. Of these, 7 patients had thrombus on CTPA, and 22 did not. Among the 37 patients without MPA dilatation, 7 had thrombus and 30 were negative for thrombus. There was no significant association between MPA dilatation and thrombus presence (chi-square $p = 0.8326$).

The sensitivity of MPA dilatation in detecting thrombus was 50%, with a specificity of 58%. The PPV was 24%, and the NPV was 81%. The ROC analysis yielded an AUC of 0.54, indicating poor discriminatory ability.

RA or RV dilatation was present in 14 patients. Of these, 5 patients had thrombus on CTPA, while 9 did not. Among the 52 patients without RA or RV dilatation, 9 had thrombus and 43 were negative. There was no statistically significant association between RA or RV dilatation and thrombus presence (chi-square $p = 0.2597$).

The sensitivity of RA or RV dilatation was 36%, specificity was 83%, PPV was 36%, and NPV was 83%. The ROC analysis showed an AUC of 0.59, indicating limited discriminatory ability.

The mean HU average in patients with thrombus on CTPA was 40.83 HU, compared to 40.74 HU in those without thrombus. An independent t-test revealed no statistically significant difference between the groups ($p = 0.969$). Logistic regression analysis further confirmed the lack of association between HU average (used as a continuous variable) and thrombus presence. The logistic regression coefficient (β) for HU average was 0.0016 ($p = 0.967$), with a 95% confidence interval ranging from -0.074 to 0.077. The model demonstrated a negligible pseudo R-squared value (0.00002), indicating that HU average did not significantly predict thrombus presence on CTPA. The ROC analysis yielded an AUC of 0.46, confirming the lack of diagnostic value for HU average in this study.

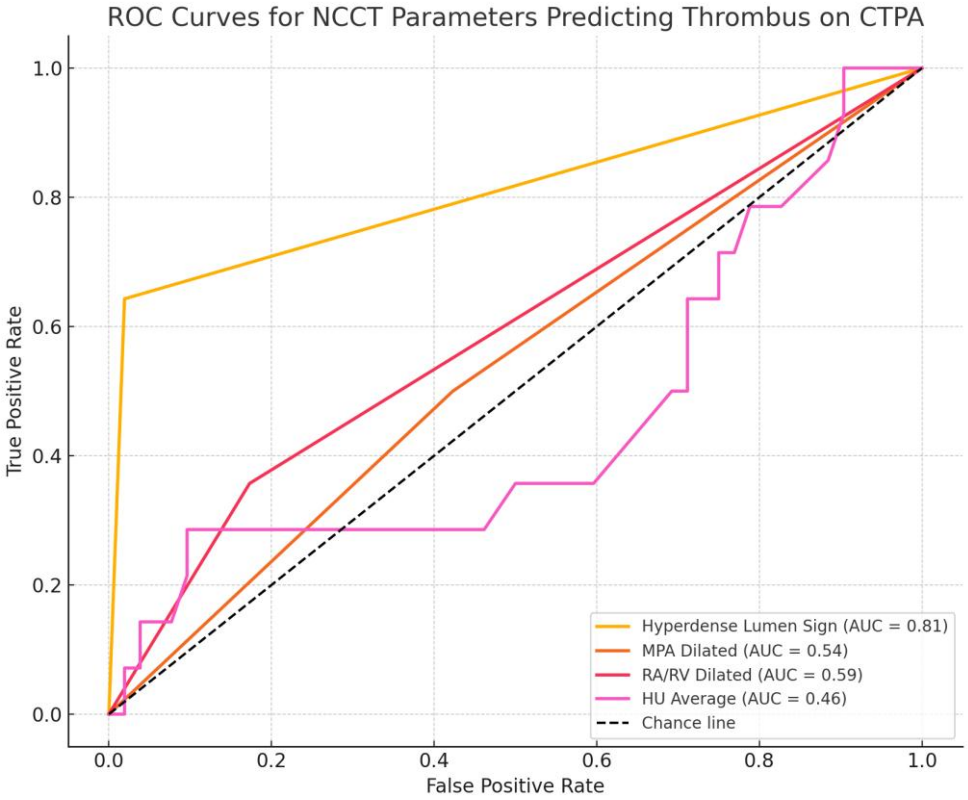
IV. Tables and Figures

Table 1. Comparison Between NCCT findings and CTPA

Parameter	Sensitivity	Specificity	PPV	NPV	Chi-Square p-value	AUC
Hyperdense Lumen Sign	64%	98%	90%	91%	< 0.0001	0.81
MPA Dilated (≥ 30 mm)	50%	58%	24%	81%	0.8326	0.54
RA or RV Dilatation	36%	83%	36%	83%	0.2597	0.59
HU Average (continuous)	-	-	-	-	0.969 (t-test)	0.46

The receiver operating characteristic (ROC) curve analysis demonstrated the highest area under the curve (AUC) for the hyperdense lumen sign (AUC = 0.81), followed by RA or RV dilatation (AUC = 0.59), MPA dilatation (AUC = 0.54), and HU average (AUC = 0.46). The ROC curves for all four parameters are shown in Figure 1.

Figure 1: ROC curves for the NCCT parameters predicting pulmonary thromboembolism on CTPA



V. Discussion

This study evaluated the diagnostic performance of non-contrast computed tomography (NCCT) chest scans in detecting pulmonary thromboembolism (PTE), using CT Pulmonary Angiography (CTPA) as the reference standard. A total of 66 patients were included, with PTE confirmed on CTPA in 14 patients (21.2%). Four specific NCCT parameters were assessed for their diagnostic value: the hyperdense lumen sign, main pulmonary artery (MPA) dilatation, right atrium or right ventricle dilatation, and average Hounsfield Unit (HU) attenuation values within the pulmonary arteries.

The hyperdense lumen sign emerged as the most reliable indicator of thrombus presence on NCCT. It demonstrated a sensitivity of 64%, specificity of 98%, positive predictive value (PPV) of 90%, and negative predictive value (NPV) of 91%. The area under the receiver operating characteristic (ROC) curve was 0.81, indicating good discriminative ability. These results align with findings from previous studies. For example, Chien et al. reported that the hyperdense embolus sign on unenhanced CT scans was a valuable indicator of central PTE, with high specificity and a significant contribution to early diagnosis in cases where contrast administration was contraindicated[6]. Similarly, Kaykisiz et al. emphasized the clinical utility of recognizing hyperdense thrombi on unenhanced chest CT for diagnosing acute pulmonary embolism, even in patients without clinical suspicion.[12]

In contrast, MPA dilatation, defined as a diameter equal to or greater than 30 mm in this study, showed limited diagnostic utility. Although MPA dilatation was present in 29 patients, it did not demonstrate a statistically significant association with thrombus presence on CTPA (chi-square p = 0.8326). The sensitivity was 50%, specificity was 58%, and the ROC AUC was 0.54. While previous studies have suggested that MPA dilatation may be a sign of pulmonary hypertension or acute right heart strain[15], our results indicate that it is not a reliable standalone marker for acute PTE in NCCT.

Right atrium (RA) and right ventricular (RV) dilatation also exhibited limited predictive value. Although this parameter showed a specificity of 83%, its sensitivity was low at 36%, and the association with thrombus presence was not statistically significant (chi-square p = 0.2597). The ROC AUC was 0.59, suggesting only marginal discriminative capacity. Previous research has emphasized the importance of RV enlargement and dysfunction in acute PE, particularly on echocardiography and contrast-enhanced CT[16]; however, RA and RV dilatation on NCCT alone does not appear to provide reliable diagnostic information.

The average HU attenuation values within the pulmonary arteries, evaluated as a continuous variable, failed to demonstrate any meaningful association with thrombus presence on CTPA. The mean HU values were nearly identical between thrombus-positive and thrombus-negative patients (40.83 HU vs. 40.74 HU, respectively). An independent t-test showed no statistically significant difference ($p = 0.969$), and logistic regression analysis confirmed the lack of association ($p = 0.967$). The ROC AUC was 0.46, indicating no diagnostic utility. Although increased HU values within the pulmonary arteries have been previously suggested as a potential marker for thrombus[17], our study found no evidence to support this approach.

Clinical Implications

The results of this study emphasize the value of the hyperdense lumen sign as a highly specific indicator of acute pulmonary embolism on NCCT chest scans. Radiologists should be vigilant in recognizing the hyperdense lumen sign on unenhanced CT, as it may prompt expedited diagnosis and management.

Conversely, the findings indicate that MPA dilatation, RA or RV dilatation, and HU attenuation values on NCCT do not provide reliable diagnostic information when considered independently. While these ancillary findings may raise suspicion for PTE in the appropriate clinical context, they should not be relied upon for diagnosis without confirmatory imaging.

Study Limitations

This study has certain limitations. First, its retrospective design and single-center setting may limit the generalizability of the findings. Second, the relatively small sample size ($n = 66$) may affect the statistical power of the results. Finally, although two radiologists independently reviewed the images and resolved discrepancies by consensus, there remains a potential for observer variability.

VI. Conclusion

This study highlights the diagnostic value of the hyperdense lumen sign on non-contrast chest CT as a reliable indicator of pulmonary embolism (PE). The hyperdense lumen sign on NCCT images demonstrated high specificity and positive predictive value, making it a valuable finding in clinically unsuspected cases of pulmonary thromboembolism.

In such cases, where CTPA is not initially considered, careful evaluation of NCCT chest scans for a hyperdense thrombus can aid in the early detection of acute PE. Prompt identification of this sign may lead to further diagnostic workup and timely management, potentially improving patient outcomes. Ancillary findings such as MPA dilatation, RA and RV dilatation, and HU averages, however, did not demonstrate sufficient diagnostic accuracy and should be interpreted cautiously.

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