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Original Article

Radiology Section

Role of Computed Tomography Pulmonary Angiography in Predicting Short-term Outcome in Patients with Pulmonary Embolism: A Retrospective Observational Study

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ABSTRACT

Introduction: Pulmonary Embolism (PE) despite advances in diagnosis and management continues to be associated with significant morbidity and mortality. Early identification of prognostic indicators is essential for risk stratification and guiding therapeutic decisions. Computed Tomography Pulmonary Angiography (CTPA), the current gold standard for PE diagnosis, also provides valuable prognostic information by quantifying embolic burden and assessing Right Ventricular Dysfunction (RVD).

Aim: To assess the role of CTPA in predicting short-term outcomes in patients with PE.

Materials and Methods: A retrospective observational study was conducted at Katuri Medical College and Hospital, Guntur, Andhra Pradesh, India, between January 2023 and June 2025. Patients diagnosed with PE on CTPA and followed for at least 30 days were included in the study. Pulmonary Artery Obstruction Index (PAOI) was calculated using the Qanadli scoring system. RVD was assessed using four CTPA parameters: Right Ventricle/Left Ventricle (RV/LV) diameter ratio, Main Pulmonary Artery (MPA) diameter, interventricular septal deviation, and contrast reflux into the Inferior Vena Cava (IVC). Outcomes at 30 days were categorised as good prognosis (discharge), Intensive Care Unit (ICU) admission, or death.

Results: A total of 85 patients were included in the study. The mean age was 54.6 years, with 51 males and 34 females. Fifty-two patients had a good prognosis, 23 required ICU admission, and 10 died within 30 days. Mean PAOI increased progressively across outcome groups (21.88±8.7, 38.91±6.3, and 45.75±14.0, respectively). MPA diameter demonstrated moderate sensitivity (78.8%) and specificity (71.2%) for predicting adverse outcomes. RV/LV ratio showed moderate sensitivity (75.8%) but low specificity (42.3%). Interventricular septal deviation and IVC contrast reflux demonstrated low sensitivity (54.5% and 42.4%, respectively) but high specificity for mortality (75.0% and 90.4%, respectively).

Conclusion: PAOI is the strongest overall predictor of adverse short-term outcome, while CT signs of RVD- particularly IVC contrast reflux and septal deviation- are highly specific markers of mortality.

Keywords: Prognosis, Pulmonary artery obstruction index, Pulmonary embolism, Right ventricular dysfunction

INTRODUCTION

The PE is a frequently underdiagnosed yet potentially fatal condition, with reported mortality rates ranging from 2-7% [1]. It is the third leading cause of cardiovascular mortality, contributing significantly to postoperative, trauma-related, and immobilisation-associated deaths [2]. Accurate prognostic assessment is crucial to identify patients who may benefit from aggressive therapies such as thrombolysis. Acute PE usually results from venous thromboembolism, with emboli obstructing the pulmonary arteries [3]. The obstruction of pulmonary arteries triggers a cascade of pathophysiological events, including acute pulmonary hypertension, increased RV afterload, RVD, and eventual circulatory collapse [1,4]. These processes also lead to the release of biomarkers useful in diagnosis and risk stratification. Elevated D-dimer reflects fibrin formation and degradation, while myocardial stretch leads to increased B-type Natriuretic Peptide (BNP) and NT-proBNP levels. Myocardial injury results in elevation of cardiac troponins and heart-type Fatty Acid-Binding Protein (h-FABP) [5,6]. The CTPA, now firmly established as the gold standard for PE diagnosis, also allows comprehensive evaluation of disease severity and prognostic markers [7]. Since embolic burden and RV haemodynamic compromise are key determinants of outcome, and most deaths due to PE occur within the first 30 days, this study evaluates the role of CTPA-derived PAOI and RVD parameters in predicting short-term outcomes in an Indian population [8,9]. While earlier studies have evaluated these parameters individually, the present study assesses them both individually and in combination [1,6,10,11]. Thus, the aim of the present study was to evaluate the utility of CTPA-derived PAOI, for individual RVD parameters, and their multi-parameter combinations in predicting short-term outcomes among Indian patients with acute pulmonary embolism.

MATERIALS AND METHODS

This retrospective observational study was conducted at Katuri Medical College and Hospital, Guntur, Andhra Pradesh, India, between January 2023 and June 2025 after Institutional Review Board approval (IEC/113/2025). Given the retrospective design and use of fully anonymised data, the requirement for informed patient consent was waived by the Ethics Committee.

Inclusion criteria: All patients, irrespective of age or sex, diagnosed with spontaneous PE confirmed on CTPA and followed for at least 30 days were included in the study.

Exclusion criteria: Patients with prior PE, pre-existing cardiac disease, chronic pulmonary disease, or other conditions predisposing to PE were excluded from the study.

Sample size: Ultimately, 85 patients met the inclusion criteria and were included in the study.

CTPA Acquisition and Image Analysis

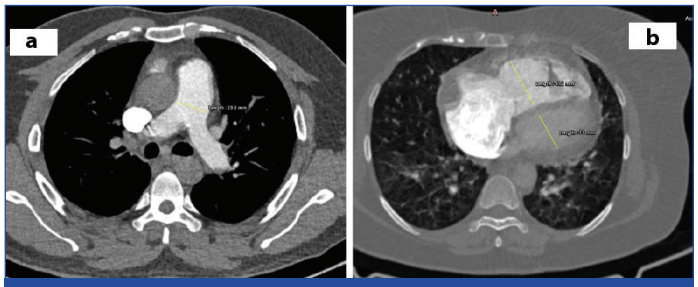
Patients with suspected PE underwent CTPA. PAOI and RVD parameters were assessed on CTPA images by two independent radiologists with 10 and 15 years of experience, who were blinded to clinical outcomes. Discrepancies were resolved by consensus.

The Qanadli score quantifies embolic burden based on the number of occluded segmental arteries and degree of obstruction. Each lung is divided into 10 segmental arteries. Partial obstruction is assigned one point and complete obstruction two points, yielding a maximum score of 40, which is expressed as a percentage

$$CTPAOI=\Sigma(n \cdot d)/40\times100$$

In the above formula n represents value of proximal thrombus in pulmonary arterial tree equal to number of segmental branches arising distally (minimum, 1; maximum, 20). And d represents a kind of weighing factor depending on degree of obstruction (no thrombus, 0; partially occluded, 1; total occlusion, 2) [12].

Standard CTPA indicators of RVD were manually quantified on a dedicated workstation using integrated electronic calipers, as follows [Table/Fig-1].



[Table/Fig-1]: Radiological reference images to measure Right Ventricular Dysfunction (RVD changes: a) Main Pulmonary Artery (MPA); b) Right Ventricle/Left Ventricle (RV/LV) diameter Ratio.

RV/LV ratio: Measured on axial images at the level of the tricuspid and mitral valves; a ratio >1 was considered abnormal [13].

MPA diameter: Measured perpendicular to the long axis of the vessel at the level of bifurcation; a diameter >30 mm was considered abnormal [14].

Interventricular septal deviation: Any deviation/bowing of interventricular septum to left is abnormal, and assessed qualitatively as present or absent [15].

IVC reflux: Defined as the presence of contrast in the IVC and hepatic veins without contrast opacification in the aorta [16].

Clinical data were obtained from medical records. Patients diagnosed with acute PE received anticoagulation therapy, thrombolysis, or a combination of both. No patient underwent embolectomy.

Outcomes at 30 days were categorised as follows:

Good outcome: Discharge without ICU admission;

Adverse outcome: ICU admission or death within 30 days.

A 5-parameter scoring model was also developed to evaluate the combined diagnostic performance by assigning 1 point to each of the following findings: PAOI ≥40%, RV/LV ratio >1.0, MPA diameter >30 mm, presence of interventricular septal deviation, and IVC contrast reflux. Patients were then stratified by total CT score to determine the sensitivity, specificity, and predictive values of a score threshold of ≥2 for identifying adverse 30-day outcomes.

STATISTICAL ANALYSIS

Data were analysed using IBM Statistical Package for the Social Sciences (SPSS) version 25.0. Quantitative variables were expressed as mean±SD and compared using the Mann-Whitney U test. Categorical variables were assessed using the Chi-square test. ROC analysis was performed to derive sensitivity, specificity, PPV, and NPV.

RESULTS

The 30-day outcomes of the 85 patients are summarised in [Table/Fig-2]. Among 85 patients, 52 had a good prognosis and 33 had adverse outcomes, 10 of whom died. The mean age of the study population was 54.6±15.6 years (range: 17-84 years), with 51 males and 34 females. No statistically significant association was found between age, sex and outcome.

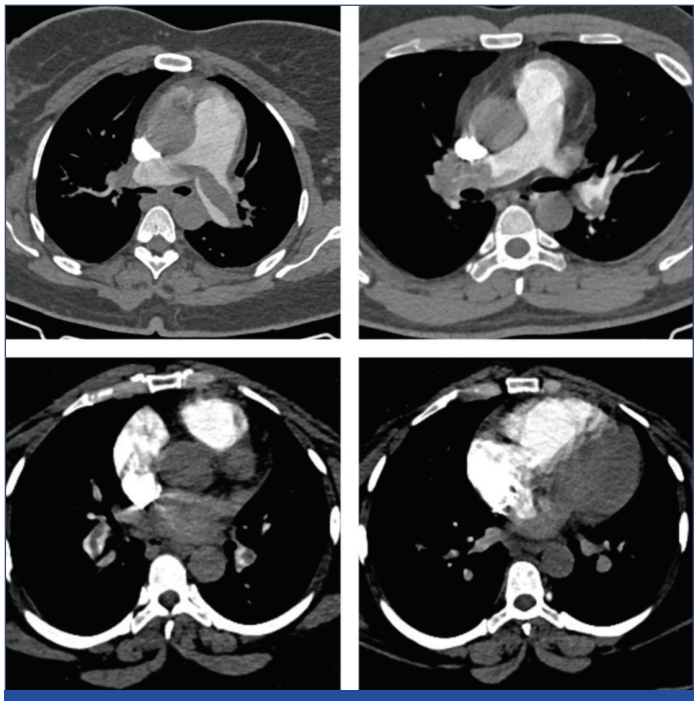
	Good prognosis		ICU admission		Death	
	Normal	Abnormal	Normal	Abnormal	Normal	Abnormal
MPA diameter	37	15	6	17	1	9
RV/LV ratio	22	30	5	18	3	7
IV septum deviation	39	13	11	12	4	6
IVC reflux	47	5	17	6	2	8

[Table/Fig-2]: Incidence of CT pulmonary angiography parameters across three outcome groups.

Mean PAOI values for discharged, ICU-admitted, and deceased patients were 21.88, 38.91 and 45.75, respectively [Table/Fig-3,4]. Following the Youden index, A PAOI ≥35 demonstrated high sensitivity (91.3%) for adverse outcome, while PAOI ≥45 showed high specificity (93.3%) for mortality [Table/Fig-5]. PAOI demonstrated excellent discriminatory ability for adverse outcome prediction (AUC=0.79) [Table/Fig-6].

Outcome Category	Count	Mean PAOI ± SD	Range (Min - Max)	
Good prognosis	52	21.88±8.7	7.5 - 42.5	-
ICU admission	23	38.91±6.3	30.0 - 50.0	< 0.001*
Death	10	45.75±14.0	30.0 - 75.0	< 0.001*

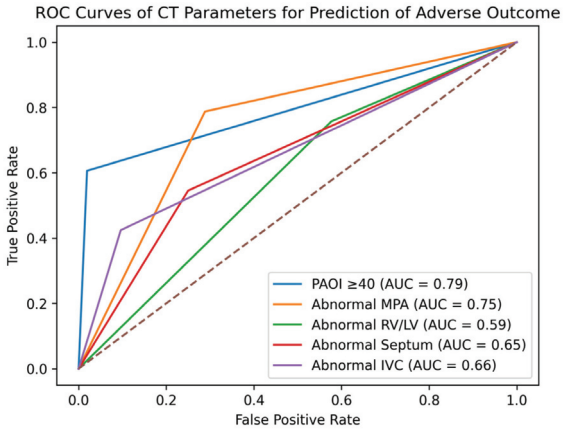
[Table/Fig-3]: Distribution of Pulmonary Artery Obstruction Index (PAOI) across outcome categories (p-values are calculated in comparison to the "Good prognosis" group.).



[Table/Fig-4]: CT pulmonary angiography images demonstrating emboli involving the main pulmonary arteries, lobar arteries, and segmental arteries.

Target outcome	Test Condition	Sensitivity	Specificity	PPV	NPV
Good prognosis	PAOI <30	76.92%	100.00%	100.00%	73.33%
Good prognosis	PAOI <45	100.00%	30.30%	69.33%	100.00%
ICU admission	PAOI ≥35	91.30%	71.15%	58.33%	94.87%
ICU admission	PAOI ≥40	69.57%	79.23%	53.33%	88.24%
Death	PAOI ≥30	100.00%	68.00%	29.41%	100.00%
Death	PAOI ≥45	60.00%	93.33%	54.55%	94.37%

[Table/Fig-5]: Diagnostic performance of PAOI thresholds for outcome prediction.



[Table/Fig-6]: Receiver Operating Characteristic (ROC) curves of CT pulmonary angiography parameters (PAOI ≥40, abnormal MPA diameter, RV/LV ratio >1, interventricular septal deviation, and Inferior Vena Cava (IVC) contrast reflux) for prediction of adverse outcome (ICU admission or death) in patients with acute Pulmonary Embolism (PE).

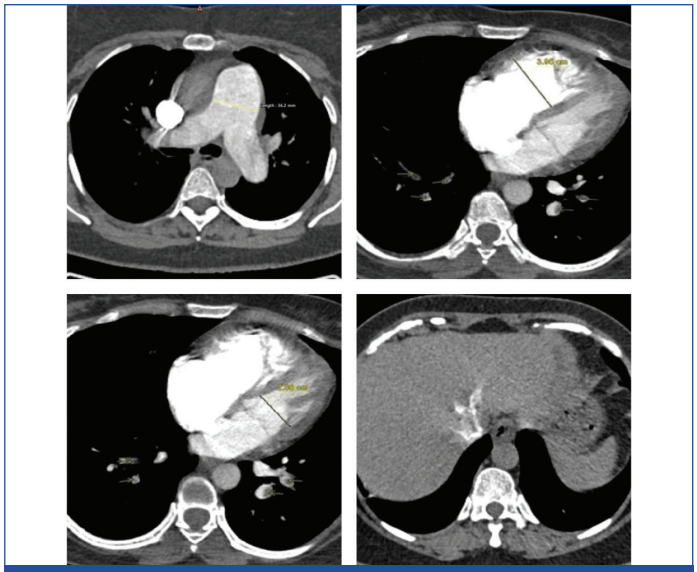
Among RVD parameters, MPA diameter showed moderate sensitivity (78.8%) and specificity (71.2%) for predicting adverse outcomes [Table/Fig-7]. Interventricular septal deviation and IVC contrast reflux showed low sensitivity but high specificity, particularly for mortality [Table/Fig-8].

CT parameter / Combination	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	p-value
PAOI ≥40	60.6	98.1	95.2	79.7	<0.001
Abnormal MPA	78.8	71.2	63.4	84.1	<0.001
Abnormal RV/LV	75.8	42.3	45.5	73.3	0.213
Abnormal septum	54.5	75.0	58.1	72.2	0.006
Abnormal IVC	42.4	90.4	73.7	71.2	<0.001
PAOI ≥40 + MPA	87.9	69.2	65.9	89.2	<0.001
PAOI ≥40 + IVC	72.7	88.5	80.0	83.6	<0.001
MPA + RV/LV	90.9	40.4	52.6	85.7	<0.001
MPA + Septum	84.8	59.6	60.9	83.8	<0.001
PAOI ≥40 + MPA + IVC	93.9	73.1	69.6	94.1	<0.001
CT Score ≥2 (5-parameter model)	97.0	75.0	71.7	97.5	<0.001

[Table/Fig-7]: Diagnostic performance of individual and combined CT parameters for predicting adverse outcome.

Among RVD parameters, IVC reflux is the most potent prognostic indicator for mortality with a 13.89-fold increase in the risk of death [Table/Fig-9].

Statistical analysis using the Chi-square test revealed that abnormal MPA and IVC were highly significant predictors of clinical outcome (p-value<0.001), while septal bowing showed moderate association (p-value=0.020). Conversely, RV/LV diameter ratio (p-value=0.213) did not demonstrate a statistically significant association with prognosis. Analysis of continuous variables showed that PAOI was significantly higher in patients with poor outcomes (mean 40.98±9.53) compared to those with good prognosis (mean 21.88±8.71; Mann-Whitney U test, p-value <0.001).



[Table/Fig-8]: Representative CT pulmonary angiography images illustrating Right Ventricular Dysfunction (RVD).

RVD parameter	Mortality fold increase (RR)	Odds Ratio (OR)	95% Confidence Interval (CI)
Abnormal MPA	9.66	12.09	1.46-100.36
Abnormal RV/LV ratio	1.27	1.31	0.31-5.50
Abnormal IV Septum	2.61	3	0.78-11.61
IVC Reflux	13.89	23.27	4.35-124.42

[Table/Fig-9]: Prognostic power of RVD parameters for mortality.

DISCUSSION

The CTPA is a rapid, non invasive modality that not only confirms PE but also provides information regarding embolic burden, RV strain, and associated cardiopulmonary conditions. To the best of our knowledge, this study is the first to evaluate PAOI, all four RVD parameters, and multiple parameter combinations for predicting short-term outcomes. In the present study, higher PAOI values were strongly associated with adverse outcomes. Osman AM and Abdeldayem EH conducted a study of 184 patients presenting with suspected acute PE, all patients underwent CTPA followed by ECHO [1]. The PAOI using the Qanadli Score was calculated and cardiac changes were recorded. The patients' outcomes were followed-up for 30 days. Only 150 patients completed the study; 26.7% needed ICU admission, while 13.3% died during follow-up. They found the PAOI cut-off values of 45% for mortality, 35% for ICU admission, and 27.5% for RVD, with 60, 75, and 90% sensitivity and 80, 73.3, and 68.6% specificity, respectively. The CT RV/LV ratio was the most sensitive parameter for predicting RV dysfunction, followed by pulmonary artery diameter [1].

According to Kang DK et al., among 260 patients with acute PE, 57 (21.9%) had adverse outcomes, including 20 deaths (7.7%) within 30 days. On multivariate analysis, abnormal interventricular septal position (HR 2.07), IVC contrast reflux (HR 2.57), RVD (4-CH)/LVD(4-CH) >1.0 (HR 2.51), and RVV/LVV >1.2 (HR 4.04) predicted adverse outcomes. For 30-day mortality, only RVD (4-CH)/LVD(4-CH) >1.0 (HR 3.68) and RVV/LVV >1.2 (HR 6.49) were significant. RVV/LVV ratio showed the strongest association with both adverse outcomes and mortality [10]. Akhoundi N et al., reported that an abnormal MPA yielded an equal sensitivity and specificity of 62.5%, whereas present study showed higher values of 78.8% and 71.2%, respectively [17].

A study by Sanchez O et al., showed that the unadjusted Risk Ratio (RR) of RV dysfunction for predicting death was 2.4 {95% Confidence Interval (CI), 1.3-4.4} [11]. In the present study, the RR was 1.27 (95% CI, 0.35-4.57), which was not statistically significant. In a study by Becattini C et al., 457 patients were included; 303 had

RVD on MDCT. In-hospital death or clinical deterioration occurred in 44 patients with and in eight patients without RVD at MDCT (14.5 vs. 5.2%; p-value=0.004) [18]. In a study conducted by Meinel FG et al., 49 studies involving 13,162 patients with acute PE (median age 61 years; 55.1% women) who underwent diagnostic CT imaging were included in the analysis. An abnormally increased RV/LV diameter ratio measured on transverse sections was associated with an approximately 2.5-fold risk for all-cause mortality {pooled Odds Ratio (OR), 2.5; 95% CI, 1.8-3.5} and adverse outcome (OR, 2.3; 95% CI, 1.6-3.4) and a 5-fold risk for PE -related mortality (OR, 5.0; 95% CI, 2.7-9.2) [8]. In the present study, it was associated with only a 1.27-fold increased risk for mortality (OR 1.31; 95% CI, 0.31-5.50).

The above differences in RV/LV ratio performance may be related to population-specific variations, non ECG-gated imaging, and timing variability.

Limitation(s)

The study was conducted using a retrospective, single-centre design, which may limit the generalisability of the results to broader populations. Furthermore, the relatively low mortality rate and the small absolute number of deaths within the cohort restricted the statistical power necessary to establish definitive associations for some parameters. Technical constraints, such as the use of non ECG-gated CT, may have introduced measurement variability in cardiac dimensions, while the assessment of the MPA diameter was limited by the use of a single threshold value. Additionally, the study lacked correlation with other prognostic tools, such as echocardiography or cardiac biomarkers, which are frequently used alongside CTPA in clinical practice.

CONCLUSION(S)

The CTPA extends beyond diagnosis to provide quantitative prognostic assessment in acute PE. PAOI is the strongest predictor of adverse outcome, while CT markers of RVD- particularly IVC reflux and septal deviation- are highly specific indicators of mortality. Routine CTPA reporting should incorporate PAOI and RVD parameters to optimise risk stratification and management.

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- iThenticate Software: May 05, 2026 (5%)

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