

Original paper

# Computed tomography pulmonary angiography for acute pulmonary embolism: prediction of adverse outcomes and 90-day mortality in a single test

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## Abstract

**Purpose:** Pulmonary embolism (PE) is a potentially fatal cardiopulmonary disease; therefore, rapid risk stratification is necessary to make decisions of appropriate management strategies. The aim of this study was to assess various computed tomography (CT) findings in order to find new prognostic factors of adverse outcome and mortality.

**Material and methods:** The study enrolled 104 patients with acute PE. Based on their outcome, patients were categorised into four groups. Comorbidities such as ischaemic heart disease were obtained from their medical records. Patients CT angiography were reviewed for recording variables such as main pulmonary artery diameter and right ventricle (RV)/left ventricle (LV) ratio. Patient deaths up to three months since diagnosis of PE had been registered. Logistic regression analysis was performed to find predictors.

**Results:** Based on multiple logistic regression, RV/LV ratio, LV diameter, and right-sided pulmonary infarction are predictors of mortality in 30 days. An RV/LV ratio of 1.19 could successfully discriminate patients who died within 30 days and those who did not.

**Conclusions:** RV/LV ratio, LV diameter, right-sided pulmonary infarction, assessed with helical CT, can help predict 30-day mortality.

**Key words:** prognostic factors, mortality, embolism.

## Introduction

Pulmonary embolism (PE) is a potentially fatal cardiopulmonary disease with a mortality rate ranging from 5% to more than 30%, depending on the patient's haemodynamic status [1-4]. Patients with PE may have different outcomes and therefore require varying intensities of clinical care. Consequently, risk assessment is necessary to make proper management strategy decisions [5-7]. Patients at high risk of adverse outcomes must be admitted to intensive care units and undergo thrombolytic treatment,

whereas hospital discharge or home treatment might be options for patients with a low probability of adverse outcomes [8,9]. Because PE may cause death after right ventricular failure and circulatory collapse, right ventricle (RV) dysfunction should be detected rapidly to identify patients who might benefit from fibrinolytic therapy [1]. Recently, computed tomography has enabled noninvasive PE diagnosis [10,11]. Every year, many patients undergo pulmonary computed tomography (CT) angiography and receive ionising radiation; therefore, it would be prudent to investigate as many CT findings as possible to identify

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A Study design · B Data collection · C Statistical analysis · D Data interpretation · E Manuscript preparation · F Literature search · G Funds collection

new predictors of adverse outcomes and mortality in these patients, to support better treatment and closer follow-up if needed. Some studies [7,12-15] have assessed the validity of CT scoring systems for pulmonary artery clot load, and others have reported RV dysfunction-related CT findings [16-21]. However, few studies have investigated the relationships among all other CT angiography findings and patients' clinical outcomes. Therefore, we conducted a study in patients with PE to define the prognostic value of CT for adverse outcomes and mortality.

## Material and methods

### Study population

The local Ethics Committee approved our retrospective study. Informed consent was waived, and patients' data were reviewed from January 2015 to January 2017. The inclusion criteria were positive PE on CT angiography study and at least three months of post-diagnosis follow-up. The exclusion criteria were chronic pulmonary embolism, cardiogenic shock, and poor quality of CT images. In total 112 patients with PE were identified. We excluded six patients because of the poor quality of images and two patients because of cardiogenic shock; a total of 104 patients were enrolled in the study.

### Clinical outcomes

According to the outcomes, patients were categorised into the following four groups: group 1 included patients who experienced adverse outcomes, defined as worse clinical conditions such as using vasopressors because of hypotension, respiratory failure, or mechanical ventilation [22,23]; group 2 included patients who died < 30 days after diagnosis of PE; group 3 included patients who died 30-90 days after diagnosis; and group 4 included patients who survived and did not experience any adverse outcomes, denoted as the OTHERS group. In our study, we considered a patient to have died of PE-related causes if (a) the autopsy report, death certificate, or medical records indicated PE as a cause of death or (b) shock was the leading cause of death in the absence of other cardiopulmonary diseases [24,25].

### Covariate collection

Information about patients' characteristics and comorbidities were obtained from the medical records [26].

The pulmonary embolism severity index (PESI) was retrospectively calculated by summing the following scores: patient age (years), male sex (10 points), cancer (30 points), heart failure (10 points), chronic lung disease (10 points), pulse rate  $\geq$  110/min (20 points), systolic blood pressure < 100 mm Hg (30 points), respiratory rate  $\geq$  30/min (20 points), temperature < 36°C (20 points), altered mental

status (60 points), and arterial oxygen saturation < 90% (20 points).

Each patient's score corresponded to the following risk classes:  $\leq$  65, class I (very low risk); 66-85, class II (low risk); 86-105, class III (intermediate risk); 106-125, class IV (high risk); and > 125, class V (very high risk) [27].

## Computed tomography pulmonary angiography studies

Computed tomography pulmonary angiography (CTPA) examinations were conducted in the craniocaudal direction by 64-multislice CT scanners (Brilliance CT scanner, Philips Healthcare) at a teaching hospital. Images were obtained with a slice thickness of 0.9 mm, reconstructed at 0.5 mm slice intervals. Intravenous administration of 120 ml of iodinated contrast medium (Visipaque 320 mg) was performed at 5-6 ml/s, timed by bolus tracking at the main pulmonary artery. The CT criterion for PE diagnosis was nonocclusive thrombus (central filling defect outlined by the contrast agent) or occlusive thrombus in normal-sized or enlarged vessels [14]. A four-chambered heart view was used, as shown by Quiroz *et al.* [28]; the maximum transverse diameters of the right and left ventricle were measured at the level of the mitral and tricuspid valve. The pulmonary trunk diameter was measured on a plane that showed the main pulmonary artery and its bifurcation, and the diameters of the right and left pulmonary artery (RPA and LPA) were measured at the same level [29]. The diameter of the aorta was determined at the middle third of the ascending part. The anteroposterior (AP) and transverse diameters of the superior vena cava (SVC) were determined at the level at which the azygos vein entered the SVC, and the AP and transverse diameters of the inferior vena cava (IVC) were measured at the level at which the IVC joined the right atrium. We measured the transverse diameter of the azygos vein at the location where it was facing the right tracheal wall and joined the SVC [30]. The following observations were also recorded: leftward interventricular septal bowing, pleural effusion, and pulmonary findings, including pulmonary infarction, sidedness of the thrombus and level of the thrombus in the pulmonary artery tree. A radiologist with six years of experience in reading thoracic CT scans reported the images, who was blinded to the clinical history [31].

### Degree of vascular obstruction

The pulmonary artery obstruction index (PAOI) was calculated by using the scoring system of Qanadli *et al.* [14]. We categorised PAOI scores into five classes:  $\leq$  8, class I; 8-16, class II; 16-24, class III; 24-32, class IV; and 32-40, class V.

### Transthoracic echocardiographic evaluation

Transthoracic echocardiography, which was performed within 24 hours of PE diagnosis, was used for

extracting information about pulmonary artery pressure [23,32,33].

### Three-month follow-up

All patient deaths up to three months after PE diagnosis were assessed by an independent committee that was given access to all patient data. The committee outlined whether a patient death should be due to PE or should be attributed to other causes [21].

### Statistical analysis

The Kolmogorov-Smirnov test was used for a normal distribution of continuous variables. Data with a normal distribution, such as PESI, were expressed as mean values with standard deviation. Parameters without normal distribution, such as age, were expressed as a median (first-third inter-quartile range). Continuous data were compared with Anova or Kruskal-Wallis tests.

Chi-square test was used for comparing discrete variables. To assess the correlation between variables, Spearman's rho and Pearson's tests were used [34]. Cut-off values for variables to detect mortality, determined by receiver-operating characteristic (ROC) plots and areas under the curve, were calculated. We also calculated the threshold value for which sensitivity equalled specificity for measurements with an  $A_z$  value significantly different from 0.5 [35]. Multiple logistic regression analyses were used to identify the predictors of adverse outcomes by using variables  $p$ -value  $< 0.05$  in univariate analysis. All statistical analyses were performed in SPSS version 24, SPSS Inc., Chicago, IL, USA.

## Results

We included 104 consecutive patients with PE in the study. Patients' demographic and clinical characteristics are shown in Table 1. Sixteen patients experienced adverse outcomes. In three months, 15 deaths occurred. An independent adjudication committee concluded that all deaths could have been related to PE. Ten deaths occurred  $< 30$  days after diagnosis, and five occurred between days 30 and 90.

The mean RV/left ventricle (LV) ratio was 1.11 (0.89-1.39), and the death within 30 days group had the highest ratio (1.44 [1.16-1.68]), followed by the adverse outcome group (1.2 [0.95-1.61]) ( $p = 0.024$ ).

The frequency of right-sided pulmonary infarction was higher among the death within 30 days group (5 [50%]) and adverse outcome group (5 [31%]), and the lowest frequency was found in the OTHERS group (7 [9%]) ( $p = 0.005$ ).

The mean IVC AP diameter was 24 mm (21-28), and the adverse outcome group (20 mm [18-24]), death 30-90 days group (20 mm [16-29]), and death within 30 days group (23 mm [20-28]) had higher scores than the OTHERS group (25 mm [22-28]) ( $p = 0.017$ ).

The azygos vein diameter was higher in the OTHERS group (10 mm [8-11]), with a  $p$ -value of 0.028. The OTHERS group had more subsegmental artery involvement (52 [71%]) than the adverse outcome (5 [31%]), death within 30 days (4 [40%]), and death within 30-90 days (1 [20%]) groups ( $p = 0.003$ ).

For the correlations between each of these three parameters (PAOI/PAOI class, PESI/PESI class, RV/LV, RV/LV class) and other variables (Table 2), Pearson's correlation and Spearman's rho test were performed. The correlation coefficients were highest between RV/LV and PAOI/PAOI class and were lower (but still significant) between the SVC transverse diameter and PAOI/PAOI class. We found a negative correlation between the LV short-axis and PAOI ( $-0.363$ ) ( $p < 0.001$ ) and a positive correlation between MPA diameter and PESI.

In assessing the correlation between the RV/LV and other variables, the analysis revealed a significant correlation between leftward ventricular septal bowing and the RV/LV ratio. Results showed a negative correlation between right sidedness of thrombus and the RV/LV ratio (Table 2).

### Predictors of outcomes at three months

Based on univariate logistic regression analysis, significant baseline predictors of adverse outcome were PESI (OR 1.01; 95% CI: 1.00-1.03;  $p = 0.031$ ), IVC AP diameter (mm) (OR 1.08; 95% CI: 1-1.17;  $p = 0.050$ ), and right sidedness of the thrombus (OR 4.68; 95% CI: 1.15-19.09;  $p = 0.031$ ), and the RV/LV ratio was a predictor of death within 30 days (OR 9.2; 95% CI: 1.35-63.02;  $p = 0.023$ ). The results showed that right-sided pulmonary infarction (OR 0.127; 95% CI: 0.03-0.535;  $p = 0.005$ ), bilateral pulmonary infarction (OR 0.241; 95% CI: 0.06-0.976;  $p = 0.046$ ), ischaemic heart disease (IHD) (OR 0.150; 95% CI: 0.036-0.624;  $p = 0.009$ ), or heart failure (HF) (OR 0.135; 95% CI: 0.027-0.677;  $p = 0.015$ ) were associated with a decreased risk of death within 30 days. Again, we found that a larger LV short-axis diameter (OR 0.089; 95% CI: 0.797-0.993;  $p = 0.038$ ) was associated with a decreased risk of death in this period. IVC transverse diameter (mm) (OR 0.786; 95% CI: 0.630-0.981;  $p = 0.033$ ) and chronic obstructive pulmonary disease (COPD) (OR 0.063; 95% CI: 0.008-0.491;  $p = 0.008$ ) were predictors of mortality in 30-90 days, both of which showed a protective role against mortality in this period.

PAOI did not show a significant association with any groups ( $p > 0.05$ ). Multivariable logistic regression analysis indicated that PESI (OR 1.01; 95% CI: 1.00-1.03;  $p = 0.046$ ) and right sidedness of the thrombus in the pulmonary tree (OR 4.5; 95% CI: 1.01-19.96;  $p = 0.048$ ) were predictors of adverse outcomes. Based on multiple logistic regression, the RV/LV ratio (OR 11.54; 95% CI: 1.16-114.35;  $p = 0.037$ ) was a strong predictor of death within 30 days. The results showed that a longer LV short axis (mm) (OR 0.813; 95% CI: 0.681-0.969;  $p = 0.021$ ) or having

**Table 1.** Comparisons of quantitative and qualitative characteristics of patients with pulmonary embolism between subgroups of mortality and adverse outcome

Object	All patients n = 104	Adverse outcome n = 16	Death < 30 days n = 10	Death 30-90 days n = 5	Others n = 73	p-value
Age, years, median (25-75 <sup>th</sup> percentiles)	62.5 (48-74)	54 (50-64)	71 (63-78)	65 (47-76)	62 (46-75)	0.200
Male gender	52 (50%)	7 (43%)	4 (40%)	4 (80%)	37 (50%)	0.482
PESI	92 ± 28	109 ± 34	94 ± 15	95 ± 8	88 ± 28	0.057
PAOI	10 (3-20)	10 (4-23)	15 (9-26)	11 (5-17)	8 (3-19)	0.247
MPA diameter (mm)	29.4 ± 3.8	31.5 ± 4.1	26.5 ± 3.1	26.6 ± 2.7	29.6 ± 3.6	0.003
RPA diameter (mm)	22 (20-23)	23 (21-24)	20 (18-21)	21 (19-22)	22 (20-24)	0.056
LPA diameter (mm)	21 (19-23)	22 (20-26)	20 (18-22)	20 (18-22)	21 (19-23)	0.087
Aorta diameter (mm)	32.8 ± 4.2	35.4 ± 3.6	33.4 ± 3.9	31.8 ± 2.7	32.3 ± 4.3	0.058
MPA/aorta ratio	0.9 ± 0.13	0.89 ± 0.10	0.80 ± 0.12	0.84 ± 0.13	0.92 ± 0.14	0.039
RV short axis (mm)	42.6 ± 8.85	44.33 ± 6.59	45.15 ± 8.89	41.86 ± 7.22	42.01 ± 9.40	0.625
LV short axis (mm)	38.19 ± 7.70	37.21 ± 6.98	32.96 ± 6.48	43.08 ± 3.37	38.79 ± 7.93	0.06
RV/LV ratio	1.11 (0.89-1.39)	1.2 (0.95-1.61)	1.44 (1.16-1.68)	0.88 (0.83-1.17)	1.03 (0.88-1.35)	0.024
SVC AP diameter (mm)	22.52 ± 4.41	21.53 ± 2.75	23.10 ± 5.97	22.76 ± 3.04	22.65 ± 4.58	0.793
IVC AP diameter (mm)	24 (21-28)	20 (18-24)	23 (20-28)	20 (16-29)	25 (22-28)	0.017
Azygos vein diameter	9.6 (8-11)	9.1 (8.27-11.5)	7.6 (6.37-10.22)	8 (6.5-8.9)	10 (8-11)	0.028
Right sided pulmonary infarction	18 (17%)	5 (31%)	5 (50%)	1 (20%)	7 (9%)	0.005
Left sided pulmonary infarction	11 (10%)	1 (6%)	1 (10%)	1 (20%)	8 (10%)	0.849
Sidedness of thrombose						
Right	95 (91%)	16 (100%)	10 (100%)	4 (80%)	65 (89%)	0.288
Left	92 (88%)	13 (81%)	10 (100%)	4 (80%)	65 (89%)	0.476
Level of thrombose						
MPA	3 (2%)	0 (0%)	0 (0%)	0 (0%)	3 (4%)	0.726
RPA	15 (14%)	1 (6%)	2 (20%)	0 (0%)	12 (16%)	0.532
LPA	11 (10%)	2 (12%)	2 (20%)	0 (0%)	7 (9%)	0.644
Lobar artery	61 (58%)	10 (62%)	9 (90%)	4 (80%)	38 (52%)	0.094
Segmental artery	88 (84%)	13 (81%)	10 (100%)	5 (100%)	60 (82%)	0.362
Subsegmental artery	62 (59%)	5 (31%)	4 (40%)	1 (20%)	52 (71%)	0.003
PAP	35 (31-50)	33.5 (25-57)	45.5 (34.5-60)	31 (24-52)	37 (32-50)	0.153

PESI – pulmonary embolism severity index, PAOI – pulmonary artery obstruction index, MPA – main pulmonary artery, RPA – right pulmonary artery, LPA – left pulmonary artery, RV – right ventricle, LV – left ventricle, SVC – superior vena cava, IVC – inferior vena cava, PAP – pulmonary artery pressure

right-sided pulmonary infarction (OR 0.111; 95% CI: 0.017-0.730;  $p = 0.022$ ) was associated with a decreased risk of mortality within 30 days, and IVC transverse diameter (mm) (OR 749; 95% CI: 0.574-0.979;  $p = 0.034$ ) and COPD (OR 0.041; 95% CI: 0.004-0.448;  $p = 0.009$ ) were associated with decreased risk of death within 30-90 days (Table 3).

Measurable variables, such as pulmonary artery pressure (PAP), PESI, and main pulmonary artery (MPA) diameter, were tested for their ability to predict survival.  $A_z$  was significantly higher than 0.5 for PESI ( $A_z = 0.667$ ), MPA diameter ( $A_z = 0.663$ ), LPA diameter ( $A_z = 0.683$ ), and aorta diameter ( $A_z = 0.639$ ) ( $p = 0.035, 0.039, 0.021,$

and 0.014, respectively). We also detected an  $A_z$  value of 0.744 and  $p = 0.011$  for the RV/LV ratio in the death within 30 days group (Table 4). For the factors which  $A_z$  was significantly higher than 0.5, Table 4 lists the threshold values for which the sensitivity equalled the specificity.

## Discussion

The study investigated the prognostic value of pulmonary CT angiography findings in patients with symptomatic PE. Below, we discuss our findings separately based on the variables that correlated with mortality or adverse outcomes.

**Table 2.** Correlation between pulmonary artery clot load, pulmonary embolism severity index, right ventricle/left ventricle, and other quantitative and qualitative computed tomography findings

Measurement and CT scan findings	PAOI/PAOI class Correlation coefficient	p-value	PESI/PESI class Correlation coefficient	p-value	RV/LV, RV/LV class Correlation coefficient	p-value
PESI	0.149	0.131	–	–	0.337	< 0.001
PAOI	–	–	0.149	0.131	0.548	< 0.001
MPA diameter (mm)	0.043	0.667	0.404	< 0.001	0.204	0.038
RPA diameter (mm)	–0.042	0.673	0.499	< 0.001	22 (20-24)	0.056
LPA diameter (mm)	0.066	0.507	0.469	< 0.001	21 (19-23)	0.087
Aorta diameter (mm)	0.000	0.996	0.361	< 0.001	0.158	0.109
MPA/Aorta ratio	0.040	0.683	0.044	0.657	0.028	0.777
RV short axis (mm)	0.426	< 0.001	0.369	< 0.001	–	–
LV short axis (mm)	–0.363	< 0.001	–0.084	0.397	–	–
RV/LV ratio	0.548	< 0.001	0.337	< 0.001	–	–
SVC transverse diameter (mm)	0.206	0.036	0.353	< 0.001	0.300	0.002
IVC AP diameter (mm)	–0.130	0.188	0.193	0.049	–0.122	0.217
IVC transverse diameter (mm)	0.010	0.920	0.265	0.007	0.244	0.012
Leftward ventricular septal bowing	–0.124	0.210	0.198	0.044	0.433	< 0.001
Reflux into inferior vena cava	–0.158	0.109	0.194	0.048	0.170	0.085
Right-sided pleural effusion	–0.120	0.224	–0.040	0.688	–0.072	0.466
Left-sided pleural effusion	–0.133	0.179	0.095	0.336	–0.071	0.474
Bilateral pleural effusion	–0.025	0.805	0.095	0.339	–0.232	0.018
Right-sided MGG opacity	0.055	0.579	0.040	0.689	–0.153	0.121
Left-sided MGG opacity	–0.154	0.119	0.203	0.039	–0.031	0.754
Sidedness of thrombose						
Right	0.049	0.619	0.020	0.841	–0.348	< 0.001
left	0.095	0.335	–0.009	0.925	0.079	0.423
Level of thrombose						
MPA	0.012	0.903	–0.008	0.937	0.260	0.008
RPA	–0.081	0.414	0.021	0.835	0.258	0.008
LPA	–0.002	0.987	0.024	0.808	0.259	0.008
Lobar artery	0.089	0.369	0.156	0.113	0.368	< 0.001
Segmental artery	0.069	0.483	0.089	0.369	0.261	0.007
Subsegmental artery	0.062	0.531	–0.089	0.371	–0.303	0.002
PAP	0.306	0.002	0.247	0.011	0.194	0.049

CT – computed tomography, PESI – pulmonary embolism severity index, PAOI – pulmonary artery obstruction index, MPA – main pulmonary artery, RPA – right pulmonary artery, LPA – left pulmonary artery, RV – right ventricle, LV – left ventricle, SVC – superior vena cava, IVC – inferior vena cava, PAP – pulmonary artery pressure

### Main pulmonary artery diameter (mm)

Our study showed that the maximum MPA diameter ( $31.5 \pm 4.1$ ) in the adverse outcome group was significantly meaningful, a finding similar to the study performed by Ilker *et al.* [29] ( $31.3$ , 95% CI:  $24.3$ – $46.4$ ) in patients who experienced adverse outcomes; however, their findings did not reach significance ( $p = 0.209$ ). In another study done by Lyhne *et al.* [7], increased diameter of the MPA

(OR = 1.08 per 1 mm increase,  $p = 0.047$ ) was associated with severe adverse outcome. Collomb *et al.* [16] found that patients with severe pulmonary embolism have larger central pulmonary artery diameters than those in other patients; we had similar findings. According to the study done by Beenen *et al.* [6], MPA enlargement was significantly associated with mortality in both the short and long term (OR 4.18 [95% CI: 1.04–16.76] at 1 week to OR 2.33 [95% CI: 1.36–3.97] after one year).

**Table 3.** Predictors of adverse outcome and mortality in 30 days and 30-90 days of 104 patients with acute pulmonary embolism

Risk factor	Adverse outcome Univariable analysis OR (95% CI) <i>p</i> -value	Multivariable analysis OR (95% CI) <i>p</i> -value	Death < 30 days Univariable analysis OR (95% CI) <i>p</i> -value	Multivariable analysis*** OR (95% CI) <i>p</i> -value	Death 30-90 days Univariable analysis OR (95% CI) <i>p</i> -value	Multivariable analysis OR (95% CI) <i>p</i> -value
Age, per year	1 (0.97-1.03) 0.873	–	1.04 (0.995-1.102) 0.076	–	0.997 (0.945-1.05) 0.919	–
Male gender	0.9 (0.36-2.21) 0.819	–	2.1 (0.503-9.02) 0.304	–	0.235 (0.025-2.18) 0.203	–
PESI	1.01 (1-1.03) 0.031	1.01 (1-1.03) 0.046	0.998 (0.974-1.02) 0.885	–	1.00 (0.973-1.03) 0.804	–
PAOI	1.01 (0.96-1.06) 0.694	–	1.07 (0.996-1.16) 0.062	–	0.992 (0.892-1.1) 0.888	–
MPA diameter (mm)	0.994 (0.88-1.11) 0.922	–	0.824 (0.678-1) 0.051	–	0.809 (0.627-1.04) 0.104	–
RPA diameter (mm)	1.08 (0.95-1.22) 0.201	–	0.844 (0.676-1.05) 0.133	–	0.884 (0.669-1.16) 0.387	–
LPA diameter (mm)	1.03 (0.908-1.18) 0.585	–	0.887 (0.710-1.107) 0.288	–	0.924 (0.696-1.228) 0.587	–
Aorta diameter (mm)	1 (0.90-1.11) 0.980	–	0.980 (0.834-1.152) 0.809	–	0.939 (0.759-1.16) 0.563	–
MPA/aorta ratio	0.984 (0.038-25.53) 0.992	–	0.012 (0.00-2.39) 0.102	–	0.033 (0.00-26.63) 0.318	–
RV short axis (mm)	1.02 (0.972-1.07) 0.388	–	1.04 (0.967-1.12) 0.280	–	0.989 (0.892-1.09) 0.834	–
LV short axis (mm)	1.00 (0.95-1.07) 0.753	–	0.89 (0.797-0.993) 0.038	0.813 (0.681-0.969) 0.021*	1.08 (0.969-1.21) 0.153	–
RV/LV ratio	1.31 (0.35-4.9) 0.679	–	9.2 (1.35-63.02) 0.023	11.54 (1.16-114.35) 0.037**	0.109 (0.003-3.92) 0.226	–
IVC AP diameter (mm)	1.08 (1-1.17) 0.050	1.05 (0.96-1.15) 0.262	0.965 (0.843-1.105) 0.608	–	0.884 (0.717-1.08) 0.244	–
IVC transverse diameter (mm)	0.971(0.894-1.05) 0.479	–	0.943 (0.827-1.075) 0.379	–	0.786 (0.630-0.981) 0.033	0.749 (0.574-0.979) 0.034
Right-sided pulmonary infarction	2.9 (0.62-13.7) 0.174	–	0.127 (0.03-0.535) 0.005	0.111 (0.017-0.730) 0.022* 0.164 (0.031-0.877) 0.035**	0.829 (0.087-7.88) 0.871	–
Left-sided pulmonary infarction	1.4 (0.29-7.34) 0.633	–	0.941 (0.106-8.323) 0.957	–	0.449 (0.046-4.42) 0.493	–
Sidedness of thrombose						
Right	4.68 (1.15-19.09) 0.031	4.5 (1.01-19.96) 0.048	–	–	2.8 (0.283-28.57) 0.375	–
Left	0.60 (0.12-2.94) 0.529	–	–	–	0.5 (0.051-4.88) 0.551	–

Table 3. Cont.

Risk factor	Adverse outcome Univariable analysis OR (95% CI) <i>p</i> -value	Multivariable analysis OR (95% CI) <i>p</i> -value	Death < 30 days Univariable analysis OR (95% CI) <i>p</i> -value	Multivariable analysis*** OR (95% CI) <i>p</i> -value	Death 30-90 days Univariable analysis OR (95% CI) <i>p</i> -value	Multivariable analysis OR (95% CI) <i>p</i> -value
Level of thrombose						
MPA	0.623 (0.05-7.17) 0.705	–	–	–	–	–
RPA	0.407 (0.129-1.28) 0.126	–	0.555 (0.104-2.96) 0.491	–	–	–
LPA	0.826 (0.202-3.38) 0.791	–	0.366 (0.066-2.03) 0.251	–	–	–
IHD	0.93 (0.303-2.90) 0.911	–	0.150 (0.036-0.624) 0.009	0.310 (0.05-1.928) 0.209 * 0.300 (0.052-1.71) 0.176**	0.950 (0.1-8.99) 0.964	–
HF	2.7 (0.321-22.75) 0.360	–	0.135 (0.027-0.677) 0.015	0.161 (0.013-2.04) 0.159* 0.314 (0.031-3194) 0.328**	0.35 (0.035-3.53) 0.375	–
COPD	0.613 (0.105-3.56) 0.586	–	–	–	0.063 (0.008-0.491) 0.008	0.041 (0.004-0.448) 0.009

\*\*\*Only variables found to significantly predict adverse outcome or mortality in 90 days by univariable analysis were entered in the multivariable model.

Two multivariable logistic regression models are used for the variables that are significantly meaningful in univariable analysis for death < 30 days group, the first one that is shown by \* includes right-sided pulmonary infarction, LV short axis (mm), IHD, and HF. The second one \*\* includes RV/LV, right-sided pulmonary infarction, IHD, and HF.

PESI – pulmonary embolism severity index, PAOI – pulmonary artery obstruction index, MPA – main pulmonary artery, RPA – right pulmonary artery, LPA – left pulmonary artery, RV – right ventricle, LV – left ventricle, SVC – superior vena cava, IVC – inferior vena cava, PAP – pulmonary artery pressure, IHD – ischaemic heart disease, HF – heart failure, COPD – chronic obstructive pulmonary disease

Our findings indicate a strong positive correlation between MPA diameter and PESI, but we did not observe a relationship between MPA diameter and PAOI, a finding that has been previously reported [30]. ROC analysis indicated that when the MPA diameter was 29.9, the sensitivity was equal to the specificity (i.e. 62.5%) for discriminating between patients who did and did not experience adverse outcomes. A similar finding was observed in the previous study [18], which found that MPA diameter could identify patients with right ventricular dysfunction, with a cut-off value of 29 mm. However, our study could not show the MPA diameter as predictive of mortality within 90 days, thus confirming the findings of a previous study [31], which was unable to demonstrate that a PA diameter > 30 mm Hg is a predictor of mortality within 30 days or adverse outcomes.

### Main pulmonary artery/aorta ratio

This ratio significantly differed among subgroups in our study; the death within 30 days group had the lowest range (0.8 ± 0.12), and the OTHERS group had the highest range (0.92 ± 0.14). These findings were similar

to those from a previous study by Ilker *et al.* [29], which demonstrated that an MPA/aorta ratio of 0.78 (0.48-0.87) in patients with mortality within 30 days was the lowest among the studied population, but, contrary to our findings, the results were not significant (*p* = 0.101). Our study did not demonstrate that the MPA/aorta ratio is a predictor of adverse outcomes or mortality, in accordance with findings from three other studies [21,30,31] in which the diameter of MPA and the MPA/aorta ratio were not found to be indicators of the mortality or severity of acute PE. We did not find any correlation between MPA/aorta and PAOI, in agreement with Ghaye *et al.* [30].

### Right ventricle/left ventricle ratio

Patients with PE and pulmonary hypertension might have right ventricular enlargement, which can lead to elevated RV/LV ratios [23]. We found the highest ratio in adverse outcomes and death in the death within 30 days group, thereby supporting findings from previous studies [21,36,37] showing a correlation between the RV/LV ratio and MDCT and mortality. Our study showed a strong positive relationship between RV/LV and PAOI along

**Table 4.** Performance of computed tomography and echocardiography measurements for discrimination of survivors from non-survivors (each mortality group), as indicated by receiver operating characteristic curves

Measurement	Adverse outcome A <sub>z</sub> value Value* p-value	Death < 30 days A <sub>z</sub> value Value p-value	Death 30-90 days A <sub>z</sub> value Value p-value	Threshold value**	Sensitivity nearly equals specificity (%)**
PAP	0.414 (0.233, 0.594) 0.274	0.638 (0.493, 0.782) 0.153	0.295 (0.000, 0.591) 0.123	NA	NA
PAOI	0.540 (0.384, 0.697) 0.608	0.679 (0.511, 0.847) 0.063	0.504 (0.257, 0.752) 0.976	NA	NA
PESI	0.667 (0.513, 0.820) 0.035	0.551 (0.410, 0.692) 0.597	0.583 (0.447, 0.719) 0.533	94.5	68.8
MPA diameter (mm)	0.663 (0.510, 0.816) 0.039	0.254 (0.101, 0.408) 0.011	0.261 (0.077, 0.444) 0.072	29.9	62.5
RPA diameter (mm)	0.652 (0.521, 0.782) 0.054	0.312 (0.161, 0.464) 0.052	0.371 (0.205, 0.537) 0.331	NA	NA
LPA diameter (mm)	0.683 (0.540, 0.825) 0.021	0.381 (0.226, 0.536) 0.219	0.408 (0.191, 0.625) 0.489	20.5	75
Aorta diameter (mm)	0.693 (0.563, 0.823) 0.014	0.528 (0.353, 0.704) 0.770	0.418 (0.235, 0.602) 0.538	32.9	75
MPA/aorta ratio	0.466 (0.334, 0.599) 0.669	0.281 (0.128, 0.434) 0.023	0.310 (0.052, 0.568) 0.153	NA	NA
RV short axis (mm)	0.593 (0.458, 0.728) 0.238	0.590 (0.397, 0.783) 0.351	0.459 (0.221, 0.696) 0.755	NA	NA
LV short axis (mm)	0.465 (0.316, 0.614) 0.656	0.280 (0.132, 0.428) 0.023	0.719 (0.587, 0.852) 0.099	NA	NA
RV/LV ratio	0.587 (0.431, 0.743) 0.270	0.744 (0.600, 0.888) 0.011	0.328 (0.132, 0.524) 0.197	1.19	80

A<sub>z</sub> values were calculated and tested for difference from 0.5. For A<sub>z</sub> values that showed difference from 0.5, threshold values were calculated for which sensitivity equalled specificity.

\*Data in parentheses are 95% confidence intervals. \*\*NA – not applicable.

PAP – pulmonary artery pressure, PAOI – pulmonary artery obstruction index, PESI – pulmonary embolism severity index, MPA – main pulmonary artery, RPA – right pulmonary artery, LPA – left pulmonary artery, RV – right ventricle, LV – left ventricle

with RV/LV and PESI; these findings are consistent with those from a previous study [38] that found a moderate to strong correlation between RV/LV and PAOI. ROC analysis indicated that an RV/LV ratio of 1.19 could successfully discriminate patients who die within 30 days from those who do not, with sensitivity equal to the specificity, at 80%; however, this cut-off point is different from those in previous studies. Quiroz *et al.* [39] set a cut-off point of 0.9, and George *et al.* [26] described a cut-off point of 1 for this purpose. Moreover, our study demonstrated that

the RV/LV ratio is a strong predictor of mortality within 30 days, thus emphasising the benefit of calculating the RV/LV ratio in patients with acute PE for determining prognosis [38]. This finding has also been shown in previous studies [38,40].

#### Inferior vena cava diameter

Based on our findings, patients who experienced adverse outcomes or mortality within 90 days had the lowest



IVC AP diameters, and the IVC transverse diameter had a weak positive correlation with PESI and the RV/LV ratio. Any increase in IVC transverse diameter was associated with a lower probability of death in 30-90 days. These results should be investigated in future larger trials.

### Right-sided pulmonary infarction

Pulmonary infarction has been reported to be associated with a lower mortality rate [40,41]. Similarly, our results showed that right-sided pulmonary infarction (RSPI) decreased the mortality within 30 days in patients with PE. In accordance with findings from previous studies [30,31,38], we did not find that pulmonary infarction was a predictor of adverse outcome and mortality within 90 days.

### Pulmonary embolism severity index

We found a moderate positive correlation between PESI and the RV/LV ratio. According to our findings with a cut-off point of 94.5, PESI successfully discriminated patients with and without adverse outcomes, with sensitivity equal to the specificity, at 68.8%.

We showed that PESI could be used as a predictor of adverse outcomes, in agreement with the findings of Choi *et al.* [27], in which PESI, NT-Pro BNP, and troponin were demonstrated to be prognostic factors of adverse outcomes.

### Pulmonary artery obstruction index

We did not find any meaningful differences in PAOI among the groups, and our results indicate that PAOI cannot be used to predict mortality or adverse outcomes. However, our findings show a strong positive correlation between PAOI and the RV/LV ratio.

### Aorta, right pulmonary artery, and left pulmonary artery diameter

Our results showed that RPA, LPA, and aorta diameter had strong, strong, and moderate positive correlations, respectively, with PESI. With the cut-off points of 20.5 mm for LPA diameter and 32.9 mm for aorta diameter, we were able to discriminate patients with and without adverse outcomes, with sensitivity equal to the specificity of 75%. According to previous studies [30], the aorta diameter is higher in non-survivors than in survivors ( $36.1 \pm 4.5$ ); these findings were similar to ours, in which the aorta diameters in the adverse outcome group ( $35.4 \pm 3.6$ ) and the mortality within 30 days group ( $33.4 \pm 3.9$ ) were higher than those in the remaining groups.

### Right ventricle and left ventricle diameter

PE, along with pulmonary hypertension, may cause right ventricular enlargement. Our study showed that the RV

and LV short-axis diameters did not differ among groups. Oz *et al.* [29] have reported similar findings, in which the LV diameter was not found to differ among patients with and without adverse clinical outcomes, and among patients who did and did not die within 30 days; however, there was a difference in RV diameter between patients with and without adverse clinical outcomes ( $p = 0.001$ ).

According to our analysis, RV diameter has a strong positive correlation with PAOI, similarly to the findings of a previous study [30]. Moreover, there was a moderate positive correlation between RV diameter and PESI. Our results showed that any increase in PAOI makes the LV diameter decrease, in accordance with findings from a previous study [30] reporting a robust negative correlation between LV diameter and PAOI.

Our study demonstrated that any decrease in LV diameter increases the probability of death within 30 days and, therefore, might be used as a predictor of mortality.

### Superior vena cava transverse diameter

Our study showed a weak positive correlation between SVC transverse diameter and PAOI, similar to the findings of a previous study [30] that did not show such a relation.

We also found a moderate positive correlation between SVC transverse diameter and PESI and the RV/LV ratio. In our analysis, the differences in the diameter of SVC among subgroups were not significantly meaningful, but Ghaye *et al.* [30] demonstrated that mean SVC diameter in non-survivors is higher than that in survivors; also, Ghuysen *et al.* [28] found a significant correlation of SVC diameter with mortality.

### Right sidedness of thrombus

According to our findings, there was a moderate negative correlation between right sidedness of the thrombus and the RV/LV ratio: right sidedness of the thrombus was correlated with a lower RV/LV ratio and was found to be a predictor of adverse outcomes.

### Chronic obstructive pulmonary disease

We found that patients with COPD were less likely to die in the 30 to 90-day period, a new finding not reported in previous studies [23,34,42].

### Limitations

The present study also has some limitations. First, our PAOI (median 10.5, range 4-20) was relatively low. Second, the potential effects of PE-specific therapy on clinical outcomes were not considered. Third, the small group size (death < 30 days; death 30-90 days; adverse outcome) may bias the results.

## Conclusions

Our study is the first attempting to find correlations between various CT findings and adverse outcomes or mortality within 90 days in four subgroups of patients with PE. We determined that RV/LV, LV diameter, and right-sided pulmonary infarction are predictors of mortality within 30 days, and IVC diameter and COPD have prognostic value in determining mortality in the 30 to 90-day period. We also found that PESI and right sidedness of the thrombus are predictors of adverse outcomes.

## Conflict of interest

The authors report no conflict of interest.

## References

- Goldhaber SZ, Visani L, De Rosa M. Acute pulmonary embolism: clinical outcomes in the International Cooperative Pulmonary Embolism Registry (ICOPER). *Lancet* 1999; 353: 1386-1389.
- Quinlan DJ, McQuillan A, Eikelboom JW. Low-molecular-weight heparin compared with intravenous unfractionated heparin for treatment of pulmonary embolism: A meta-analysis of randomized, controlled trials. *Ann Intern Med* 2004; 140: 175-183.
- Douketis JD, Kearon C, Bates S, et al. Risk of fetal pulmonary embolism in patients with treated venous thromboembolism. *JAMA* 1998; 279: 458-462.
- Buller HR, Davidson BL, Decousus H, et al. Subcutaneous fondaparinux versus intravenous unfractionated heparin in the initial treatment of pulmonary embolism. *N Engl J Med* 2003; 349: 1695-1702.
- Torbicki A, Perrier A, Konstantinides S, et al. Task Force for the Diagnosis and Management of Acute Pulmonary Embolism of the European Society of Cardiology (ESC). Guidelines on the diagnosis and management of acute pulmonary embolism. *Eur Heart J* 2008; 29: 2276-2315.
- Beenen L, Bossuyt P, Stoker J, Middeldrop S. Prognostic value of cardiovascular parameters in computed tomography pulmonary angiography in patients with acute pulmonary embolism. *Eur Respir J* 2018; 52: pii: 1702611.
- Lyhne MD, Schultz JG, MacMahon PJ, et al. Septal bowing and pulmonary artery diameter on computed tomography pulmonary angiography are associated with short-term outcomes in patients with acute pulmonary embolism. *Emerg Radiol* 2019; 26: 623-630.
- Wan S, Quinlan DJ, Agnelli G, Eikelboom JW. Thrombolysis compared with heparin for the initial treatment of initial treatment of pulmonary embolism: a meta-analysis of the randomized controlled trials. *Circulation* 2004; 110: 744-749.
- Squizzato A, Galli M, Dentali F, Ageno W. Outpatient treatment and early discharge of symptomatic pulmonary embolism: a systematic review. *Eur Respir J* 2009; 33: 1148-1155.
- Stein PD, Fowler SE, Goodman LR, et al. Multidetector computed tomography for acute pulmonary embolism. *N Engl J Med* 2006; 354: 2317-2327.
- Zhang LJ, Lu GM, Meinel FG, et al. Computed tomography of acute pulmonary embolism: state-of-the-art. *Eur Radiol* 2015; 25: 2547-2557.
- Vedovati MC, Germini F, Agenelli G, Becattini C. Prognostic role of embolic burden assessed at computed tomography angiography in patients with acute pulmonary embolism: systematic review and meta-analysis. *J Thromb Haemost* 2013; 11: 2092-2102.
- Bankier AA, Janata K, Fleischmann D, et al. Severity assessment of acute pulmonary embolism with spiral CT: evaluation of two modified angiographic scores and comparison with clinical data. *J Thoracic Imaging* 1997; 12: 150-158.
- Qanadli SD, El Hajjam M, Vieillard-Baron A, et al. New CT, index to quantify arterial obstruction in pulmonary embolism: comparison with angiographic index and echocardiography. *AJR Am J Roentgenol* 2001; 176: 1415-1420.
- Mastora I, Remmy-Jardin M, Massen P, et al. Severity of acute pulmonary embolism: evaluation of a new spiral CT angiographic score in correlation with echocardiographic data. *Eur Radiol* 2003; 13: 29-35.
- Collomb D, Paramelle PJ, Calaque O, et al. Severity assessment of acute pulmonary embolism: evaluation using helical CT. *Eur Radiol* 2003; 13: 1508-1514.
- Araoz PA, Gotway MB, Trowbridge RL, et al. Helical CT pulmonary angiography predictors of in-hospital morbidity and mortality in patients with acute pulmonary embolism. *J Thorac Imaging* 2003; 18: 207-216.
- Gutte H, Mortenson J, Mark ML, et al. Non-ECG-gated CT pulmonary angiography and the prediction of right ventricular dysfunction in patients suspected of pulmonary embolism. *Clin Physiol Funct Imaging* 2017; 37: 575-581.
- Bach AG, Nansalmaa B, Kranz J, et al. CT pulmonary angiography findings that predict 30-day mortality in patients with acute pulmonary embolism. *Eur J Radiol* 2015; 84: 332-337.
- Wu AS, Pezzullo JA, Cronan JJ, et al. CT pulmonary angiography :quantification of pulmonary embolus as a predictor of patient outcome-initial experience. *Radiology* 2004; 230: 831-835.
- Van der Meer RW, Pattynama PM, Van Strijen MJ, et al. Right ventricular dysfunction and pulmonary obstruction index at helical CT: prediction of clinical outcome during 3-month follow-up in patients with acute pulmonary embolism. *Radiology* 2005; 235: 798-803.
- Konstantinides S, Gebel A, Heusel G, et al. Heparin plus alteplase compared with heparin alone in patients with submassive pulmonary embolism. *N Engl J Med* 2002; 347: 1143-1150.
- Jimenez D, Lobo JL, Monreal M, et al. Prognostic significance of multidetector CT in normotensive patients with pulmonary embolism: results of the PROTECT study. *Thorax* 2014; 69: 109-115.
- Casazza F, Becattini C, Bongarzone A, et al. Clinical features and short term outcomes of patients with acute pulmonary embolism. The Italian Pulmonary Embolism Registry (IPER). *Thromb Res* 2012; 130: 847-852.
- Laporte S, Mismetti P, Decousus H, et al. Clinical predictors of fetal pulmonary embolism in 15,520 patients with venous thromboembolism: findings from the Registro Informatizado de la Enfermedad Trombo-Embolica venosa (RIETE) Registry. *Circulation* 2008; 117: 1711-1716.
- George E, Kumamaru KK, Ghosh N, et al. Computed tomography and echocardiography in patients with acute pulmonary embolism: part 2 prognostic value. *J Thoracic Imaging* 2014; 29: W7-W12.

27. Keum-Ju C, Seung-Ick C, Kyung-Min S, et al. Prognostic implications of computed tomographic right ventricular dilation in patients with acute pulmonary embolism. *Thromb Res* 2013; 113: 182-186.
28. Ghuyesen A, Ghaye B, Willems V, et al. Computed tomographic pulmonary angiography and prognostic significance in patients with acute pulmonary embolism. *Thorax* 2005; 60: 956-961.
29. Oz II, Altinsoy B, Serifoglu I, et al. Evaluation of right atrium-to-right ventricle diameter ratio on computed tomography pulmonary angiography: prediction of adverse outcome and 30-day mortality. *Eur J Radiol* 2015; 84: 2526-2532.
30. Ghaye B, Ghuyesen A, Willems V, et al. Severe pulmonary embolism: pulmonary artery clot load scores and cardiovascular parameters as predictors of mortality. *Radiology* 2006; 239: 884-891.
31. Sen HS, Abakay O, Cetincakmak MG, et al. A single imaging modality in the diagnosis, and prognosis of pulmonary embolism. *Bioméd Res Int* 2014; 2014: 470295.
32. Grifoni S, Olivotto I, Cecchini P, et al. Short term clinical outcome of patients with pulmonary embolism, normal blood pressure and echocardiographic right ventricular dysfunction. *Circulation* 2000; 101: 2817-2822.
33. Sanchez O, Trinquart L, Caille V, et al. Prognostic factors for pulmonary embolism: the PREP study, a prospective multicenter cohort study. *Am J Respir Crit Care Med* 2010; 181: 168-173.
34. Ozsu S, Karaman K, Mentese A, et al. Combined risk stratification with computerized tomography/echocardiography and biomarkers in patients with normotensive pulmonary embolism. *Tromb Res* 2010; 126: 486-492.
35. Hanley JA, McNeil BJ. The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology* 1982; 143: 29-36.
36. Schoepf UJ, Kucher N, Kipfmüller F, et al. Right ventricular enlargement on chest computed tomography. *Circulation* 2004; 110: 3276-3280.
37. Gibson NS, Sohne M, Buller HR. Prognostic value of echocardiography and spiral computed tomography in patients with pulmonary embolism. *Curr Opin Pulm Med* 2005; 11: 380-384.
38. Heyer CM, Lemburg SP, Knoop H, Holland T. Multidetector-CT angiography in pulmonary embolism – can image parameters predict clinical outcome? *Eur Radiol* 2011; 21: 1928-1937.
39. Quiroz R, Kucher N, Schoepf UJ, et al. Right ventricular enlargement on chest computed tomography: prognostic role in acute pulmonary embolism. *Circulation* 2004; 20: 2401-2404.
40. Tajarerernmuang P, Euathrongchit J, Liwsrisakun C, et al. Computed tomographic pulmonary angiographic findings to predict adverse outcomes in acute pulmonary embolism. *Crit Care* 2015; 19: 327.
41. Lobo JL, Zorrilla V, Arizpuru F, et al. Clinical syndromes and clinical outcome in patients with pulmonary embolism: findings from the RIETE registry. *Chest* 2006; 130: 1817-1822.
42. Becattini C, Agnelli G, Vedovati MC, et al. Multidetector computed tomography for acute pulmonary embolism: diagnosis and risk stratification in a single test. *Eur Heart J* 2011; 32: 1657-1663.