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Prognostic significance of radiological parameters in patients with acute pulmonary embolism: a retrospective observational study

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ABSTRACT

Aims: Acute pulmonary embolism (PE) is a significant global cause of mortality. This study aimed to evaluate the prognostic relationship between radiological parameters obtained from computed tomography pulmonary angiography (CTPA) in patients with acute PE. PE is an important cause of mortality all over the world. In this study, we aimed to investigate the prognostic correlation between radiological parameters in CTPA in patients with acute PE.

Methods: This study included 227 patients diagnosed with PE who underwent CTPA upon admission to a tertiary emergency department (ED) between January 1, 2019, and July 1, 2021. We compared 24 patients (10.6%) who died with 203 patients (89.4%) who survived. Clot burden was assessed by calculating the Qanadli score (Qscore) from CTPA images. The study evaluated several radiological parameters, including the Qanadli score (Qscore), main pulmonary artery (PA) diameter, ascending aorta (AO) diameter, AO/PA ratio, right ventricular (RV) to left ventricular (LV) diameter ratio (RV/LV ratio), and inferior vena cava (IVC) reflux. Short-term mortality within one month was tracked, and mortality rates were determined accordingly.

Results: The Qscore demonstrated limited accuracy in predicting mortality, with a sensitivity of 41% and a specificity of 44% (AUC: 0.415, 95% CI 0.312–0.518, p=0.175). IVC reflux was an indicator of RV dysfunction. Compared to surviving patients, those who died exhibited a lower incidence of IVC reflux, with a statistically significant difference (p=0.047). The RV/LV and AO/PA ratios did not show significant associations with mortality. In contrast, AO and PA diameters were found to be predictors of mortality, with sensitivities of 66% and 61%, and specificities of 66% and 62%, respectively (AO: AUC 0.683, 95% CI 0.562–0.804, p=0.03; PA: AUC 0.651, 95% CI 0.514–0.788, p=0.016).

Conclusion: Overall, the study concluded that the Qscore from CTPA was not a reliable prognostic indicator of mortality in PE patients admitted to the emergency department. In contrast, the diameters of the AO and PA emerged as potential predictors of mortality.

Keywords: Pulmonary embolism, qanadli score, radiologic parametres, mortality

INTRODUCTION

Pulmonary embolism (PE) is defined as embolic occlusion of the pulmonary arterial system. It is the third leading cause of cardiovascular death, following stroke and myocardial infarction.[1,2] Acute PE is estimated to cause more than 100,000 deaths annually worldwide.[3] The majority of deaths from acute PE, exceeding 70%, occur within the first few hours to several days after onset. Mortality rates are particularly elevated within the first hour.[4] Prompt recognition of acute PE is crucial for timely diagnosis and effective treatment. Although the clinical presentation of acute PE ranges from asymptomatic cases to sudden death, approximately 81% of patients present with dyspnea, 50% with hypoxia, and 70% with tachycardia.[5] Risk stratification in patients with acute PE is essential for guiding appropriate treatment and optimizing patient management.[6] In a recent study comparing auxiliary diagnostic methods in PE, a statistical significance was found between massive involvement of computed tomography pulmonary angiography (CTPA) and echocardiography results. It has been shown that echocardiography is preferable as an auxiliary radiological method in the diagnosis of massive PE.[7] However, CTPA is the preferred initial imaging test for patients with suspected PE due to its high sensitivity and specificity.[8] According to the European Society of Cardiology PE guidelines, CTPA is recommended for patients with a high suspicion of PE, even

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in cases of hemodynamic instability. Additionally, in patients with low or intermediate clinical probability, a normal CTPA result effectively rules out the diagnosis of PE without the need for further investigation.[9] Several studies have explored the potential role of CTPA as a tool for assessing patient prognosis in cases of PE.[6,10,11] Previous studies have demonstrated that right heart dysfunction and PE identified on CTPA are potential prognostic markers.[12,13] The Qanadli score (Qscore) is one of the embolic obstruction indices in CTPA that has been shown in studies to have prognostic value. Clot burden can be used to assess the presence, location, and extent of arterial occlusion.[6,13] Patients with right ventricular (RV) dysfunction are known to have a high mortality rate, even if their hemodynamics are initially stable. RV dysfunction can be used as an indicator to predict the clinical outcomes of patients with acute PE.[6]

The objective of this study was to investigate the relationship between various multidetector CTPA parameters and short-term mortality in patients with acute PE.

METHODS

This study was designed as a retrospective observational study. Patients who presented to the emergency department of a tertiary care center between January 1, 2019, and July 1, 2021, and were diagnosed with PE via CTPA were included. A total of 2,913 patients who had previously undergone CTPA were analyzed. Ethical approval for this study was obtained from Akdeniz University Faculty of Medicine Clinical Researches Ethics Committee (Date: 20/04/2022, Decision No: 2022-KAEK-266). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

The requirement for informed consent was waived due to the retrospective nature of the study. Of the initial patient pool, 268 were identified with a diagnosis of acute PE, with 41 excluded based on the exclusion criteria. Ultimately, 227 patients were included in the final analysis. Inclusion criteria consisted of patients aged 18 years or older and those with a confirmed diagnosis of PE via CTPA. Patients whose CTPA parameters could not be measured due to contrast media incompatibility, as well as those with undetermined treatment or outcome criteria, were excluded from the study (Figure 1). Socio-demographic information for all patients was obtained from the hospital's information-recording system. Each patient's Wells score was calculated using clinical data and the following criteria: clinical signs of deep venous thrombosis (DVT) (3 points), pulmonary thromboembolism (PTE) as the most likely diagnosis (3 points), heart rate >100/minute (1.5 points), recent surgery or immobilization within the last month (1.5 points), history of prior DVT or PTE (1.5 points), hemoptysis (1 point), and malignancy (1 point).

Measurements of Image on CTPA

All CTPA images were acquired in the emergency department using a Toshiba ACTIVION 16 (TSX-031A, Japan) multislice CT scanner. The images were initially reviewed by an emergency physician. In cases of indeterminate image interpretation, a final decision was made after discussion and review by an emergency physician with at least 10 years of experience in chest CT for pulmonary emergencies. PE-related parameters were measured and recorded on patient data forms. CTPA cross-

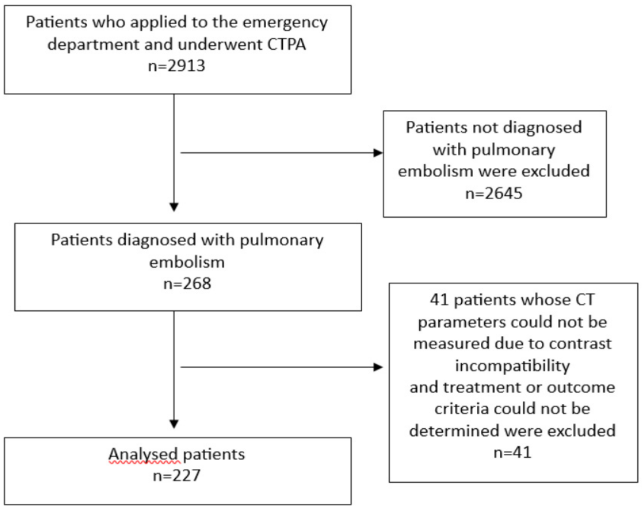

Figure 1. Patient flow chart

sectional scans were processed and analyzed to assess right heart function. The following CT landmarks were assessed: the RV to left ventricular (LV) diameter ratio (RV/LV ratio), the ratio of the main pulmonary artery (PA) diameter to the ascending aorta (AO) diameter (AO/PA ratio), the diameter of the superior vena cava (SVC), and the morphology of the interventricular septum. The widest point of the heart on the axial CT images was used to measure the diameters, including the maximum diameters of the right and left ventricles on CTPA images. Transverse sections were measured between the inner aspect of the interventricular septum and the free wall of the ventricles, perpendicular to the long axis of the heart. The RV/LV ratio was then calculated. The diameters of the main pulmonary artery and the ascending aorta were measured from transverse sections adjacent to the main pulmonary artery and right pulmonary artery, respectively, followed by the calculation of the AO/PA ratio. The diameters of the SVC and azygos vein were measured at the point where the azygos vein joins the SVC on transverse CT images. All radiological parameters are illustrated in Figure 2. The convexity of the interventricular septum bowing towards the left ventricle was also examined. Reflux into the inferior vena cava (IVC) and the reflux of contrast material into the hepatic vessels were assessed using axial images.[6]

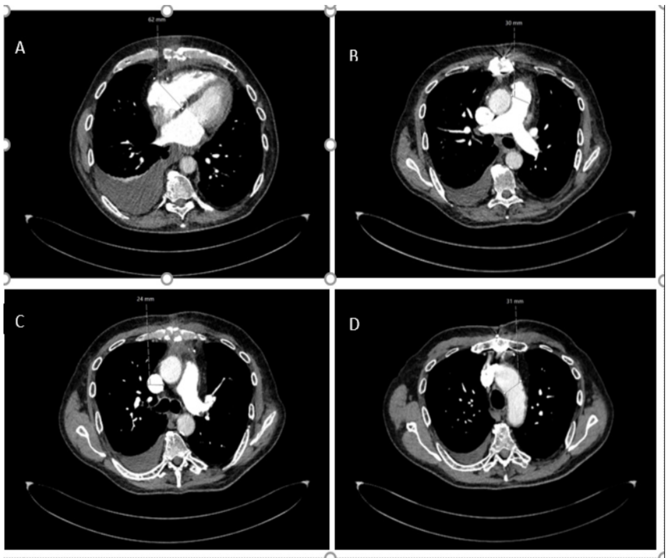

Figure 2. CTPA of a male patient 70 aged shows that measuremts of radiologic paremeters. **A.** (RV diameter), **B.** (pulmonary arter diameter), **C.** (superior vena cava diameter), **D.** (ascenden aorta diameter)

The Qanadli score was calculated using the formula (n×d)/40×100, where 'n' represents the number of segmental branches affected by the proximal thrombus in the pulmonary artery tree (ranging from 1 to 20), and 'd' denotes the degree of occlusion in the pulmonary artery (0 for no occlusion, 1 for partial occlusion, and 2 for complete occlusion).[12]

Primary Outcome

Short-term mortality was defined based on the 1-month mortality rate of the patients. To determine the 30-day mortality rate, the hospital records of all patients discharged within 30 days after PTCA were reviewed. When available, mortality information was gathered through telephone interviews with the patients. If personal interviews were not possible, mortality information was obtained directly from relatives. The patients were then classified into two groups: the survival group and the mortality group. The relationship between the measured parameters and mortality following PTCA was analyzed.

Statistical Analysis

Descriptive statistical analyses were performed using SPSS version 25.0 (Statistical Package for Social Sciences), with statistical significance set at p<0.05. Technical abbreviations were explained upon first use. The normality of the data was assessed using the Kolmogorov-Smirnov test. For continuous variables with a normal distribution, mean and standard deviation values were calculated, while median and interquartile ranges were used for non-parametric and non-normally distributed data. Chi-square and Fisher's exact tests were applied to compare categorical variables. Independent t-tests were used for normally distributed variables, and Mann-Whitney U tests for non-normally distributed variables. Logistic regression analysis was conducted to identify potential factors affecting mortality. Receiver operating characteristic (ROC) curves were analyzed, and the area under the curve (AUC) was calculated to determine optimal cut-off values for the AO and PA diameters, as well as Qscore.

RESULTS

The mean age of all patients was 59.73±16.76 years, with 127 (55.90%) being male. Dyspnea was the most common presenting complaint, reported by 155 patients (68.30%). Among the comorbid conditions examined, malignancy was present in 83 patients (36.60%). Short-term mortality analysis revealed that 24 patients (10.60%) died within one month. The mortality and survival groups were compared based on PE-related clinical parameters. The median respiratory rate was significantly higher in the mortality group compared to the survival group (30 vs. 24, p<0.001). The median oxygen saturation was significantly lower in the mortality group compared to the survival group (90 vs. 94, p=0.039). The main demographic and clinical characteristics of the patients are detailed in Table 1. This study investigated the correlation between radiological parameters and mortality in patients undergoing PTCA. The results indicated that the mean Qscore was significantly lower in the mortality group compared to the survival group (6.92±5.80 vs. 9.97±8.50, p=0.027). Additionally, the mortality group had significantly higher measurements of AO and PA diameters compared to the survival group (35.54±6.38 vs. 32.07±5.10, p=0.002, and 29.66±5.74 vs. 27.16±4.14, p=0.049, respectively). The incidence of IVC reflux, an indicator of RV dysfunction, was lower in the mortality group compared to the survival group, with a statistically significant difference between the two groups (p=0.047). The relationship between each measurement parameter in PTCA and PE and their impact on survival is presented in Table 2. Table 3 summarizes the results of the multivariate logistic regression analysis, which identified several independent factors influencing mortality, with respiratory rate showing statistical significance (p=0.05). Mortality cut-off values for AO diameter, PA diameter, and Qscore were calculated as 33.50, 28.50, and 5.50, respectively (Figure 3).

However, at this specific cut-off value, the Qscore did not predict mortality effectively, with a sensitivity of 41% and a specificity of 44% (AUC: 0.415, 95% CI 0.312–0.518, p=0.175). In contrast, the AO and PA diameters demonstrated better predictive value, with AO showing a sensitivity of 66% and specificity of 66%, and PA with a sensitivity of 61% and specificity of 62%. These reduced sensitivity and specificity values were linked to mortality (AO: AUC 0.683, 95% CI 0.562–0.804, p=0.03; PA: AUC 0.651, 95% CI 0.514–0.788, p=0.016).

Table 1. The relationship of demographic and clinical parameters with survival due to PE

Variables (n=24)	Mortality, n (%)	Survival (n=203)	p
Gender (female/male)	13 (54.2)/11 (45.8)	87 (42.9)/116 (57.1)	0.291
Age>70	12 (50)	58 (28.6)	0.320
Prior history of surgery	1 (4.2)	15 (7.4)	0.477
Prior histroy of PE	0 (0)	16 (7.9)	0.230
Malignancy	13 (54.2)	70 (34.5)	0.058
Heart failure	1 (4.2)	4 (2)	0.431
Chronic lung disease	4 (16.7)	32 (15.8)	0.550
Dyspnea	19 (79.2)	136 (67)	0.226
Palpitation	2 (8.3)	15 (7.4)	0.697
Wells score (IQR)	5.5 (4.12-5.87)	4.5 (4-5.5)	0.348
Chest pain	0 (0)	87 (100)	<0.001
Vital parameters, (IQR)			
SBP	126 (111-141)	126 (111-141)	0.330
DBP, (mean±SD)	81.21±13.062	77.77±14.403	0.237
Heart rate, beats/min;	110 (91-127)	107 (92-121)	0.784
Respiratory rate	30 (28-36)	24 (20-28)	<0.001
SpO_2	90 (81-95)	94 (88-97)	0.039

IQR: Interquartile range, * At admission, SpO_2: Blood oxygen saturation, SBP: Systolic blood pressure, PE :Pulmonary embolism , SD: Standart deviation

Table 2. The relationship between measurement parameters on CTPA and survival due to PE.			
Variables	**Mortality (n=24)**	**Survival (n=203)**	**p**
*VCS	19.29±4.87	19.67±3.78	0.709
*Aort	35.54±6.38	32.07±5.10	0.002
*PA	29.66±5.74	27.16±4.14	0.049
*AO/PA	1.22±0.21	1.19±0.19	0.483
*LA	28.79±8.77	29.98±7.74	0.482
*RV	34.91±9.22	33.08±7.43	0.268
*LV	33.20±9.03	34.94±9.17	0.381
*RV/LV	1.12±0.40	1.01±0.38	0.183
*Qscore	6.92±5.80	9.97±8.50	0.027
βPresence of obstruction,	17 (70)	152 (74)	0.668
βSeptal bowing	1 (4.2)	9 (4.4)	0.714
βPresence of pleural effusion	11 (45.8)	66 (32.5)	0.192
βPresence of pulmonary infarction	3 (12.5)	61 (30)	0.092
βIVC reflux	4 (16.7)	10 (4.9)	0.047

*mean±SD, independent t test was used. β n (%), chi-squared and Fishear exact test was used. VCS: Superior vena cava diameter, AORT: Ascending aorta diameter (mm), PA: Pulmonary artery diameter (mm), AO/PA: Ascending aorta/pulmonary artery diameter LA: Left atrium diameter RV: Right ventricular diameter, RV/LV: Right ventricle/left ventricle diameter, Qscore: Qanadli score, IVC: Vena cava inferior, PE: Pulmonary embolism, CTPA: Computed tomographic pulmonary angiography

Table 3. Variables related to deaths at the end of the 1st month				
Variables related to mortality	**B±SE**	**OR**	**(%95 CI)**	**p**
† AO	-0.070±0.049	0.933	(0.847-1.027)	0.156
† PA	-0.062±0.059	0.940	(0.837-1.055)	0.293
† Qanadli score	0.066±0.034	1.068	(0.999-1.141)	0.052
† Respiratory rate	-0.107±0.039	0.898	(0.833-0.969)	0.005
† IVF reflux	-0.291±0.723	0.748	(0.181-3.087)	0.688
† SpO_2	0.013±0.036	1.013	(0.945-1.086)	0.720

DSO:89
B±SE: Regression coefficient and standard error, **AO:** Ascending aorta diameter, **PA:** Pulmonary artery diameter **SpO_2:** Oxygene saturation

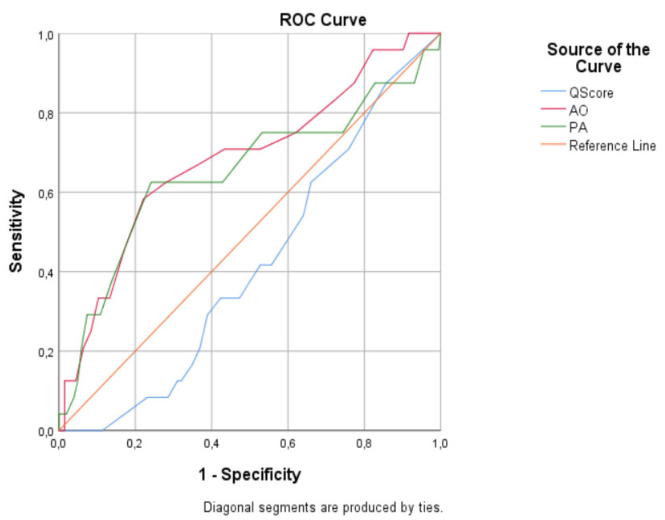

Figure 3. The prognostic accuracy of the ascending aorta (AO) diameter, main pulmonary artery (PA) and Qanadli score (Qscore) to predict mortality. The ROC curve shows that the area under the curve (AUC) revealed that the area of risk stratification, Qscore, AO, and PA diameters were 0.415 (95%CI: 0.312-0.518, p=0.175), 0.683 (95%CI: 0.562-0.804, p=0.003) and 0.651 (95%CI: 0.514-0.788,p=0.016), respectively.

DISCUSSION

This study examined the relationship between clinical and radiological parameters and short-term mortality in patients with acute PE in the emergency department. The findings revealed several simple yet useful parameters that could assist emergency physicians in the rapid and early management of acute PE, a condition with potentially fatal outcomes. Among the clinical parameters, patients with a fatal outcome were found to have lower oxygen saturation (SpO_2) and were tachypneic. Notably, respiratory rate emerged as an independent predictor of mortality. Our study demonstrated that although the Qscore, one of the radiological parameters, was associated with mortality, its low sensitivity and specificity limit its utility as a prognostic marker. The variability in the prognostic value of the Qscore reported in the literature suggests that no definitive cut-off value has been established for this score. In a study by Hefeda et al.[6] which included 32 patients with a 30-day mortality follow-up, a Qscore above 18 was identified as a predictor of mortality, though it showed a weak correlation. In a similar study by Wei-Ming Huang et al.[14] which included 201 patients with acute PE, a mean Qscore of 6.8±4.0 was not found to be significant in predicting mortality. In another study conducted by Cozzi et al.[10] including 780 acute PE patients in the emergency department, the mean Qscore was 17.6±12.7, and no prognostic relationship with short-term mortality was identified. In fact, the severity of PE is believed to be influenced not only by clot size and thrombus extension but also by the underlying cardiac condition.[15] These findings are consistent with numerous other studies and meta-analyses in the literature, and can be explained by the underlying pathophysiology.[16-18] Furthermore, the calculation of the Qanadli score, being a semi-quantitative technique, poses challenges due to its low reproducibility and high inter-observer variability. As a result, it may have limited prognostic value in the emergency department, particularly since it is often reported with a delay.

According to the ESC PE Guidelines, mild RV dilatation, defined as an RV/LV ratio above 0.9, is observed in over 50% of hemodynamically stable patients. Its clinical significance is minimal, and it is associated with low risk.[9] However, studies in the literature suggest that an RV to LV ratio greater than 1 is associated with poorer outcomes.[19-21] In our study, no significant correlation was found between the RV/LV ratio and mortality. Similar findings have been reported in the literature. For example, a study by Araoz et al.[22] found no significant association between an increased RV/LV ratio and poor 30-day outcomes. In contrast, our study found that the presence of IVC reflux was significantly associated with mortality when compared to the survivor group, though it was not identified as an independent factor affecting mortality. Nonetheless, previous studies have demonstrated that both IVC reflux and an RV/LV ratio exceeding 1.2 are indicative of poor prognosis.[6] In a study conducted by Ghaye et al.[16] involving 82 patients, both the RV/LV ratio and the presence of IVC reflux were significantly different between the mortality and survival groups. Additionally, this study demonstrates that the diameters of the AO and PA, two radiological parameters associated with PE, may predict mortality above specific thresholds. There is limited literature on the prognostic correlation of radiological parameters in PE. Ghaye et al.[16] conducted a study comparing the relationship between AO and PA diameters in CTPA with respect to mortality predictors in the mortality and survival groups. In the mortality group, the mean diameters of the aorta and pulmonary artery were 36.1±4.5 mm and 32.2±3.8 mm, respectively. In contrast, the ascending aorta diameter was significantly greater in the survival group, though it has been shown to predict mortality with low sensitivity and specificity. However, no significant relationship between PA diameter and mortality could be demonstrated.[16]

Limitations

The first limitation of this study is its single-center, retrospective design. Secondly, the challenges associated with calculating the Qscore may have influenced the results. We recommend that future researchers conduct large cohort studies to enhance clinical efficiency by minimizing operator errors through the use of various semi-automated and artificial intelligence software.

CONCLUSION

In conclusion, this study demonstrated that the Qscore is not a reliable prognostic parameter for predicting mortality in PE patients in the emergency department. In contrast, the diameters of the AO and PA are associated with mortality, albeit with low sensitivity and specificity.

ETHICAL DECLARATIONS

Ethics Committee Approval

Ethical approval for this study was obtained from Akdeniz University Faculty of Medicine Clinical Researches Ethics Committee (Date: 20/04/2022, Decision No: 2022-KAEK-266).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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