DOI: 10.4274/jarem.galenos.2023.16769
J Acad Res Med 2023;13(3):131-137

Relationship Between Shock Index, sPESI Score, and Right Ventricular Dysfunction in CTPA with Mortality in Patients Diagnosed with Acute PTE in the Emergency Department

Acil Serviste Akut PTE Tanısı Alan Hastalarda Şok İndeksi, sPESI Skoru ve Sağ Ventrikül Disfonksiyonun Mortalite ile İlişkisi

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Cite this article as: İşcan Er B, Melekoğlu A, Altınbilek E, Öztürk D. Relationship Between Shock Index, sPESI Score, and Right Ventricular Dysfunction in CTPA with Mortality in Patients Diagnosed with Acute PTE in the Emergency Department. J Acad Res Med 2023;13(3):131-137

ABSTRACT

Objective: Pulmonary thromboembolism (PTE) is a cardiovascular disease that occurs as a result of occlusion of the main pulmonary artery and/or its branches due to thrombus or another reason, requiring urgent diagnosis and treatment. Several scoring systems are used to predict mortality due to PTE. In our study, we aimed to show the superiority of the right ventricular/left ventricular (RV/LV) ratio in predicting 30-day mortality using simplified pulmonary embolism severity index (sPESI), shock index (SI), and computed tomography pulmonary angiography (CTPA).

Methods: This was a retrospective, cross-sectional study. The study was conducted on patients diagnosed with acute PTE who were admitted to the Emergency Department of University of Health Sciences Turkey, Şişli Hamidiye Etfal Training and Research Hospital between January 01, 2017 and November 17, 2021. Demographic characteristics, clinical features, and vital parameters of the patients were recorded. SI, sPESI score, and RV/LV ratio were calculated. SI ≥1.0, sPESI ≥1.0, and RV/LV ≥1.0 were considered high risk.

Results: A total of 205 patients, of which 55.6% were female, were included in the study. The mean age of the patients in our study was 67.1±16.6 (minimum-maximum =20.0-105.0). We found statistically significant differences in sPESI, SI, and RV/LV ratio between the mortality and survival groups ($p<0.05$). In our study, we accepted PESI [area under the curve (AUC) =0.776] as the gold standard and performed receiver operating characteristic curve analysis to determine mortality in sPESI (AUC =0.697), SI (AUC =0.654), and RV/LV ratio (AUC =0.605). We found that the sPESI, SI, and RV/LV ratios were moderately predictive and statistically significant, respectively ($p<0.001$, $p<0.001$, $p=0.001$, $p=0.0028$).

Conclusion: We believe that CTPA can be used as a single procedure for diagnosis and risk stratification in patients with acute PTE. SI, sPESI, and RV/LV ratios were found to be significant in predicting 30-day mortality.

Keywords: Computed tomography pulmonary angiography, mortality, PESI, pulmonary thromboembolism, RV/LV ratio, SI, sPESI

ÖZ

Amaç: Pulmoner tromboemboli (PTE), acil tanı ve tedavi gerektiren ana pulmoner arter ve/veya dallarının trombüs veya başka bir nedenle tıkanması sonucu ortaya çıkan kardiyovasküler bir hastalıktır. PTE'nin mortalitesini öngörmek amacıyla bazı skorlama sistemleri kullanılmaktadır. Çalışmamızda basitleştirilmiş pulmoner emboli şiddet indeksi (sPESI), şok indeksi (SI) ve bilgisayarlı tomografi pulmoner anjiyografide (BTPA) sağ ventriküler/sol ventriküler (RV/LV) oranının 30 günlük mortaliteyi öngörmede üstünlüklerini göstermeyi amaçladık.

Yöntemler: Çalışmamız Sağlık Bilimleri Üniversitesi, Şişli Hamidiye Etfal Eğitim ve Araştırma Hastanesi Acil Servisi'ne 01 Ocak 2017-17 Kasım 2021 tarihleri arasında başvuran akut PTE tanısı almış hastaların incelendiği retrospektif ve kesitsel bir araştırmadır. Hastaların demografik ve klinik özellikleri, vital parametreleri kaydedildi. SI, sPESI skoru ve RV/LV oranı hesaplandı. SI ≥1,0, sPESI ≥1,0 ve RV/LV ≥1,0 yüksek risk olarak kabul edildi.

Bulgular: Çalışmaya alınan toplam hasta sayısı 205 olup, %55,6'sını kadın, %44,4'ünü erkek cinsiyet oluşturmaktaydı. Çalışmamızdaki hastaların yaş ortalaması 67,1±16,6 (minimum-maximum =20,0-105,0) olarak saptandı. sPESI, SI, RV/LV oranını mortalite görülen grupta istatistiksel olarak anlamlı saptadık ($p<0,05$). Çalışmamızda PESI'yi [eğri altında kalan alan (AUC) =0,776] altın standart kabul ederek, sPESI (AUC =0,697), SI (AUC =0,654) ve RV/LV oranının (AUC =0,605) mortaliteyi saptamak açısından alıcı işletim karakteristik eğrisi analizini yaptık, sırasıyla sPESI, SI ve RV/LV oranının orta düzeyde prediktif ve istatistiksel olarak anlamlı olduğunu saptadık ($p<0,001$, $p<0,001$, $p=0,001$, $p=0,0028$).

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Received Date/Geliş Tarihi: 13.04.2023 **Accepted Date/Kabul Tarihi:** 24.10.2023

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Sonuç: Akut PTE'li hastalarda, tanı ve risk sınıflandırması için BTPA'nın tek bir prosedür olarak kullanılabileceğini düşünüyoruz. SI, sPESI ve RV/LV oranlarının 30 günlük mortaliteyi öngörmede anlamlı olduğu saptandı.

Anahtar kelimeler: Bilgisayarlı tomografi pulmoner anjiyografi, mortalite, PESI, pulmoner tromboemboli, RV/LV oranı, SI, sPESI

INTRODUCTION

Pulmonary thromboembolism (PTE) is the occlusion of the pulmonary artery and/or its branches by a thrombus carried through the systemic veins. This occlusion may also occur due to non-thrombotic reasons (1,2). PTE is a cardiovascular disease that requires urgent diagnosis and treatment, which has an increased frequency of diagnosis in emergency services in parallel with the developments in imaging methods; however, it still has a high mortality rate (3,4). Pulmonary angiography is the gold standard in the diagnosis of PTE, but it is not easy to perform. Computed tomography pulmonary angiography (CTPA) has come to the forefront because it is non-invasive and easily accessible (5,6). The ratio of the right ventricle to the left ventricle, which can be an indicator of right ventricular dysfunction, can be easily measured in CTPA. Although many methods such as shock index (SI) and pulmonary embolism severity index (PESI) have been developed to predict mortality at the next stage of diagnosis and treatment of PTE, there are some difficulties in its use (7,8). Therefore, several other scoring systems have been developed that are easier to use than PESI, such as simplified PESI (sPESI), SI, and ratio of ventricular diameters [right ventricular/left ventricular (RV/LV)] showing RV dysfunction in CTPA. sPESI, which is calculated using the combination of patients' demographic characteristics, vital parameters, clinical findings, and additional comorbidities, is useful in predicting mortality together with pulse/systolic blood pressure (SI) and RV/LV ratio in CTPA (9,10).

Therefore, in this study, we aimed to compare SI, sPESI score, and RV/LV ratio in terms of mortality in acute PTE in the emergency department (ED).

METHODS

In this retrospective study, the files of acute PTE patients admitted to the ED of the University of Health Sciences Turkey, Şişli Hamidiye Etfal Training and Research Hospital were obtained from the hospital data processing system. This study was approved by the University of Health Sciences Turkey, Şişli Hamidiye Etfal Training and Research Hospital Health Application and Research Center Clinical Research Ethics Committee (decision no: 1937, date: 23.11.2021).

Patients and Study Design

This study included patients who were admitted to the ED of our hospital between January 01, 2017 and November 17, 2021, diagnosed with acute PTE confirmed by CTPA, and whose diagnosis and treatment protocols were complete in the electronic health record system. Patients who were under the age of 18 years, pregnant, had missing data on the system, and whose mortality information was not available in the system were excluded from the study.

Data Collection

The University of Health Sciences Turkey, Şişli Hamidiye Etfal Training and Research Hospital Information Management System (HIMS) was used to collect data.

Information regarding the demographic characteristics of the patients such as age and gender, complaints such as dyspnea, chest pain, hemoptysis, syncope, dizziness, leg pain/swelling, and confusion, vital parameters (systolic and diastolic blood pressure, respiratory rate, pulse and oxygen saturation) and history of previous or known disease were obtained from HIMS. Radiology images were also obtained from HIMS to determine SI, RV/LV on CTPA, and sPESI score. SI ≥1.0, sPESI ≥1.0, and RV/LV ≥1.0 were considered high risk (8,11).

CTPA findings were accessed through HIMS. The diameter ratio of the ventricles (RV/LV) was measured in the valvular plane of the two-dimensional axial transverse plane. Patients with an RV/LV ratio ≥1.0 in CTPA were considered to be at high risk for 30-day mortality (12). CTPA recordings were made using 128-Slice Siemens SOMATOM Definition Edge (Siemens, Erlangen, Germany). Imaging interpretations were performed by radiologists, and RV/LV ratios were calculated by the researchers. In CTPA, the RV short axis in the axial orientation was measured at the level of the tricuspid valve in the basal third of the ventricle. Measurements were made from the inner wall to the inner wall at the widest point. It was considered that the short axes of RV and LV could be found at different axes of CT levels in the same patient. The images in Figure 1a and b were accessed using HIMS.

We obtained the 30-day mortality information of the patients through the Ministry of Health Death Notification System.

Statistical Analysis

In the descriptive statistics of the data, the mean, median, minimum-maximum (min-max), standard deviation, frequency, and ratio values were used. The distribution of variables was analyzed using the Kolmogorov-Smirnov test. The chi-square test was used in the analysis of qualitative independent data, and the Fisher

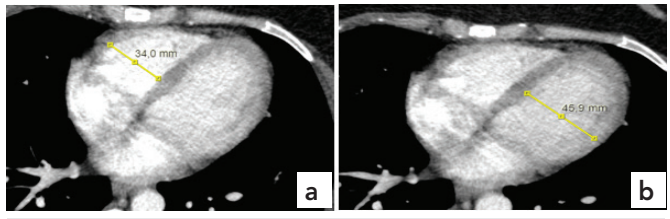

Figure 1. a) Measurement of the right ventricle at the widest point in the short axis from the inner wall to the inner wall, b) Inner wall to inner wall measurement of the left ventricle at its widest point in the short axis

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Exact test was used when the chi-square test conditions were not met. Independent sample t-test and Mann-Whitney U test were used in the analysis of quantitative independent data. Receiver operating characteristic (ROC) curve analysis was performed to determine the cut-off values of the RV/LV ratio in predicting mortality in sPESI, SI, and CTPA. SPSS 28.0 (IBM) program was used in the analysis. The Medcalc statistic program was used for ROC curve comparison.

RESULTS

Two hundred five patients were included in the study. The number of women (114) was higher than that of men (91). The mean age of the patients in our study was 67.1±16.6 years (min-max =20.0-105.0 years), and the median age was 69 years.

The mean age of the patients in the mortality group was higher than that in the survival group (p<0.001). Gender distribution in the mortality and survival groups was similar (p>0.05). The frequency of dyspnea, chest pain, hemoptysis, syncope, dizziness, and leg pain/swelling was similar in the mortality and survival groups (p>0.05). The frequency of confusion was higher in the mortality group than in the non-mortality group (p<0.001; Table 1).

In the mortality group, systolic and diastolic blood pressures were lower than those in the survival group. The heart rate did not significantly differ between groups (p>0.05). The respiratory rate in the mortality group was higher than that in the survival group. The O_2 saturation value in the mortality group was lower than that in the survival group (Table 2).

The mean values of neutrophil lymphocyte ratio (NLR), urea, and lactate levels were higher in the mortality group than in the survival group (p=0.001). Hemoglobin, creatinine and Na+, pH, PO_2, PCO_2, D-dimer levels and troponin levels were similar in both groups (p>0.05; Table 3).

PESI and sPESI scores were higher in the mortality group. The SI and RV/LV ratio on CTPA were higher in the mortality group (Table 4).

We performed ROC curve analysis to determine the highest specificity and sensitivity point of our study with the new cut-off value.

ROC curve analysis was performed to determine the predictive value of PESI for mortality. The area under the curve (AUC) value shown in Figure 2 was found to be 0.776 with moderate-to-high significance [p<0.001, 95% confidence interval (CI) 0.702-0.851, Table 5].

ROC curve analysis was performed to determine the predictive value of SI for mortality. The AUC value shown in Figure 2 was found to be 0.654, with moderate (p=0.001, 95% CI 0.563-0.746, Table 5).

ROC curve analysis was performed to determine the predictive value of the RV/LV ratio for mortality in patients with CTPA. The AUC value shown in Figure 2 was found to be 0.605, with moderate (p=0.028, 95% CI 0.520-0.689, Table 5).

Table 1. Comparison of demographic characteristics and complaints on admission to the ED in mortality and survival groups

		Mortality (-)			Mortality (+)			p-value
		Median ± SD		25-75 per	Median ± SD		25-75 per	
Age		67.0±16.7		54-77	78.5±12.8		67.5-84	**<0.001[m]**
		n	%		n	%		
Gender	Female	92	58.6%	-	22	45.8%	-	0.119[X²]
	Male	65	41.4%	-	26	54.2%	-	
Dyspnea	(-)	27	17.2%	-	3	6.3%	-	0.060[X²]
	(+)	130	82.8%	-	45	93.8%	-	
Chest pain	(-)	95	60.5%	-	33	68.8%	-	0.302[X²]
	(+)	62	39.5%	-	15	31.3%	-	
Hemoptysis	(-)	154	98.1%	-	44	91.7%	-	0.054[X²]
	(+)	3	1.9%	-	4	8.3%	-	
Syncope	(-)	140	89.2%	-	40	83.3%	-	0.279[X²]
	(+)	17	10.8%	-	8	16.7%	-	
Dizziness	(-)	147	93.6%	-	47	97.9%	-	0.249[X²]
	(+)	10	6.4%	-	1	2.1%	-	
Leg pain/swelling	(-)	121	77.1%	-	42	87.5%	-	0.117[X²]
	(+)	36	22.9%	-	6	12.5%	-	
Confusion	(-)	155	98.7%	-	41	85.4%	-	**<0.001[X²]**
	(+)	2	1.3%	-	7	14.6%	-	

[m]Mann-Whitney U test, [X²]chi-square test (Fisher test), SD: standard deviation, ED: emergency department, per: percentile

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Table 2. Comparison of vital findings at the time of admission to the ED between mortality and survival groups

	Mortality (-)		Mortality (+)		p-value
	Median ± SD	25-75 per	Median ± SD	25-75 per	
Systolic BP (mmHg)	120.0±21.2	110-130	110.0±21.6	96-120	**0.001**[m]
Diastolic BP (mmHg)	71.0±12.4	64-71	70.0±13.1	60-80	**0.009**[m]
Pulse/min (heart rate)	100.0±19.8	89-100	110.0±21.3	96-120	0.052[m]
Respiratory rate	20.0±3.7	18-20	20.0±6.5	20-29.5	**<0.001**[m]
O_2 saturation	92.0±9.5	78-92	88.5±7.8	80-91	**0.006**[m]

[m]Mann-Whitney U test, SD: standard deviation, ED: emergency department, BP: blood pressure, per: percentile

Table 3. Comparison of hematological parameters in terms of mortality

	Mortality (-)		Mortality (+)		p-value
	Median ± SD	25-75 per	Median ± SD	25-75 per	
Hg	12.6±1.8	11.3-13	12.5±1.9	10-13.6	0.437[m]
NLR	4.2±7.4	2.7-6.3	7.0±5.7	3.6-10.3	**0.001**[m]
Urea	40.0±21.3	28-53	50.5±37.1	39-73	**0.001**[m]
Cre	0.9±0.4	0.76-1.0	1.0±0.5	0.7-1.4	0.264[m]
Na^+	137.0±5.2	135-139	138.0±5.9	133-140	0.736[m]
K^+	4.2±0.5	3.8-4.6	4.5±0.6	4.0-4.8	**0.003**[m]
pH	7.4±0.1	7.38-7.45	7.4±0.1	7.33-7.46	0.255[m]
PO_2	66.0±25.0	46-89	60.0±23.6	47-82	0.356[m]
PCO_2	35.0±9.4	32-43	35.5±7.2	32-42	0.538[m]
Lactate	2.0±1.1	1.4-2.5	2.8±2.0	1.4-3.9	**0.005**[m]
D-dimer ($x10^3$)	2.5±9.8	2100-7600	2.5±17.0	2150-36600	0.313[m]
Troponin	0.1±2.9	0.01-0.09	0.1±1.5	0.4-0.89	0.084[m]

[m]Mann-Whitney U test, Cre: creatinine, Hg: hemoglobin, NLR: neutrophil lymphocyte ratio, SD: standard deviation, per: percentile

Table 4. Comparison of clinical scores in terms of mortality

	Mortality (-)		Mortality (+)		p-value
	Median ± SD	25-75 per	Median ± SD	25-75 per	
PESI score	106.0±34.8	82.5-130	144±42.2	117-172	**<0.001**[m]
sPESI score	1.0±1.24	0.5-2.0	2.5±1.25	1.25-3.0	**<0.001**[m]
Shock index	0.85±0.23	0.7-1.0	0.98±0.34	0.8-1.33	**0.001**[m]
RV/LV	1.11±0.8	0.97-1.33	1.2±0.8	1.06-1.36	**0.028**[m]

[m]Mann-Whitney U test, SD: standard deviation, PESI: pulmonary embolism severity index, sPESI: simplified pulmonary embolism severity index, RV/LV: right ventricular/left ventricular

We compared the independent variables for which we analyzed the ROC curve for mortality. We found that the PESI score differed from the others (Table 6).

DISCUSSION

Two hundred five patients with acute PTE were included. In this study, we compared the sPESI, SI, and RV/LV ratio for mortality in patients with acute PTE, and found that sPESI had the highest sensitivity and reliability.

The mean age of our patients was advanced (67.1±16.6). In a study by Gök and Kurtul (12), the mean age was found to be 64±16 years and 63±15 years in the study by Secemsky et al. (13). In our study, the mean age was found to be higher than that in other studies. It was thought that the mean age was high because our hospital is an advanced tertiary center and serves elderly patients with high comorbidities.

We divided the patients into groups with and without mortality. In the group with mortality, we found that the mean age was significantly higher than that in the group with no mortality. In the study statistics of Erarslan et al. (14), advanced age was found to be statistically significant. Advanced age is the independent variable for mortality and is the most important risk factor for mortality in many diseases such as PTE.

Among the patient groups, only blurred consciousness was significantly more pronounced in the mortality group than in the

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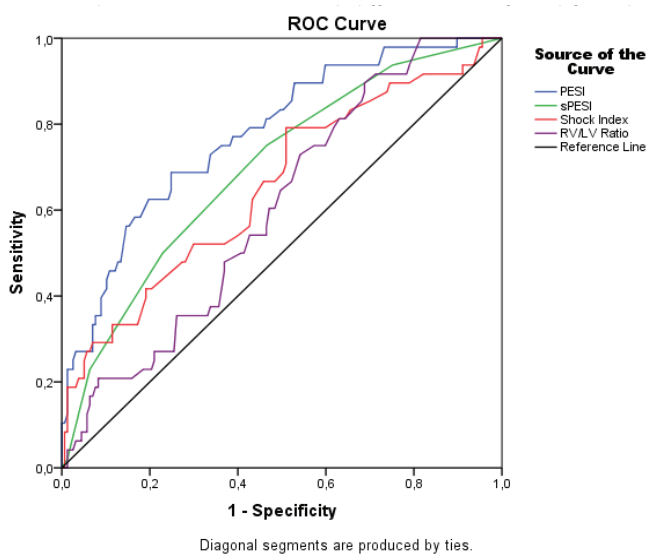

Figure 2. ROC curve analysis for mortality of all variables
ROC: receiver operating characteristic, PESI: pulmonary embolism severity index, sPESI: simplified pulmonary embolism severity index, RV/LV: right ventricular/left ventricular

with PTE, as well as those that occur in tissue perfusion disorders, for the prognosis.

PESI and sPESI are scoring systems developed to predict 30-day morality based on clinical parameters (17). When we compared the groups in terms of RV/LV ratio in PESI, sPESI, SI, and CTPA, which are the parameters we investigated in our study, we found that all of them were higher and statistically significant in the mortality group.

In our study, we accepted PESI (AUC =0.776) as the gold standard and performed ROC curve analysis to determine mortality in sPESI (AUC =0.697), SI (AUC =0.654), and RV/LV ratio (AUC =0.605) in CTPA. We found that the RV/LV ratio was moderately predictive and statistically significant for sPESI, SI, and CTPA, respectively ($p<0.05$).

Among these independent variables, sPESI (93.8%) had the highest sensitivity, followed by RV/LV ratio (91.7%) and SI (72.6%). Among these variables, sPESI has the highest negative predictive value (94.3%).

In Venetz et al. (18), PESI and sPESI scores were compared and the estimated 30-day mortality within each risk group was analyzed. The total 30-day mortality was 9.3%. In the study, PESI classified a significantly greater proportion of patients as low risk than sPESI. PESI and sPESI had similar sensitivities (90% vs. 89%), negative predictive values (98% vs. 97%), and negative odds ratios (0.23 vs. 0.28) for predicting mortality. The original PESI was found to have a significantly higher discrimination power than the sPESI (18). In our study, the sensitivities of PESI and sPESI were similar to those in the literature and had high values.

The SI has been investigated in many disease groups in the ED. Some of these are diseases that carry a risk of shock, such as acute PTE and myocardial infarction, sepsis, trauma, bleeding, and ruptured ectopic pregnancy. SI >1.0 was found to be commonly associated with increased mortality, emphasizing the need for an aggressive treatment approach in these patients (19). In PTE, the heart rate increases to send the decreased amount of blood returning to the left ventricle to the systemic circulation at a sufficient level due to the clot load caused by PTE. The SI value increases with increasing heart rate and decreasing systolic pressure. In our study, parameters such as systolic blood pressure, heart rate, syncope due to hypotension, blurred consciousness, and elevated lactate levels resulting from perfusion disorder came to the forefront with regard to mortality in patients with high SI compared with patients with low SI. In our study, SI was determined to be an independent risk factor for mortality in the univariate model. Among the other parameters, SI had the highest specificity in predicting mortality (72.6%).

One study concluded that SI is an important predictor of in-hospital death, myocardial necrosis, and RV dysfunction. The efficacy of SI in predicting in-hospital death was found to be high for the distinction between PTE patients with a lower and higher risk of in-hospital death after acute PTE (20). A study by Kucher et al. (21) concluded that time-consuming imaging tests can be avoided to reduce the risk of sudden death and not delay reperfusion therapy in patients with PTE and high SI.

In a large meta-analysis, an abnormally increased ratio of right and LV diameters (>2.5-fold) measured in cross-sections was associated with a 5-fold risk of pulmonary embolism-related death (22). In the study of Robert et al. (23), AUC for RV/LV ratio was found to be 0.77 (95% CI: 0.62-0.99) for the estimation of all-cause 30-day mortality. In our study, we found that the variable with the lowest predictive value for mortality was the RV/LV ratio (AUC =0.605) in CTPA, but its sensitivity was 91.7%. In a study investigating whether RV dilatation can be used to evaluate the risk of acute pulmonary embolism in CTPA, RV dilatation detected by CT was associated

Table 5. ROC analysis of PESI, sPESI, shock index, RV/LV to predict 30-day mortality in PTE

	AUC	Sensitivity	Specificity	Cut-off	95% CI	p-value
PESI	0.776	68.8%	75.2%	128	0.702-0.851	**<0.001**
sPESI	0.697	75.0%	53.5%	1.5	0.613-0.780	**<0.001**
SI	0.654	79.2%	49.0%	0.825	0.563-0.746	**0.001**
CT RV/LV	0.605	89.6%	31.2%	1	0.520-0.689	**0.028**

ROC: receiver operating characteristic, PESI: pulmonary embolism severity index, sPESI: simplified pulmonary embolism severity index, CT: computed tomography, RV/LV: right ventricular/left ventricular, CI: confidence interval, AUC: area under the curve, SI: shock index, PTE: pulmonary thromboembolism

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Table 6. Comprasion of ROC curves

		sPESI	SI	RV/LV
PESI	p	**0.001**	**0.001**	**0.001**
sPESI	p	-	0.349	0.11
SI	p	-	-	0.43

ROC: receiver operating characteristic, PESI: pulmonary embolism severity index, sPESI: simplified pulmonary embolism severity index, SI: shock index, RV/LV: right ventricular/left ventricular

with an increased 30-day mortality in all hemodynamically stable patients presenting with pulmonary embolism (24). In our study, we found a high sensitivity of RV/LV ≥1 (91.7%) to exclude mortality in acute PTE. Based on our statistical analyses, we believe that multislice CTPA can be used as a single procedure for diagnosis and risk stratification in patients with acute PTE.

Study Limitations

Our study was retrospective, single-center, and the number of patients was limited. In addition, some hematological data were not evaluated because biomarkers showing myocardial damage, such as heart-type fatty acid binding protein, and RV dysfunction, such as B-type natriuretic peptide (BNP) and N-terminus-proBNP, were not studied in our hospital. The compatibility and correlation of these parameters, which have been found to be associated with mortality, with the scores and indexes subject to our study in terms of mortality could not be evaluated.

CONCLUSION

Scoring systems such as sPESI, SI, and RV/LV ratio were found to be significant and moderately predictive in predicting 30-day mortality in patients with PTE. It has been observed that PESI is the most valuable scoring method because of its inclusiveness. When we compared sPESI, SI, and RV/LV ratios, sPESI had the highest specificity and reliability. SI was the scoring method with the highest specificity. RV/LV on CT was the most sensitive in terms of mortality. In multivariate regression analysis, age and respiratory rate were shown to be effective in predicting mortality. Because these parameters are simple to measure in the emergency room, they can be used to determine prognosis. We believe that CTPA can be used as a reliable method in predicting mortality and as a diagnostic tool.

Ethics Committee Approval: This study was approved by the University of Health Sciences Turkey, Şişli Hamidiye Etfal Training and Research Hospital Health Application and Research Center Clinical Research Ethics Committee (decision no: 1937, date: 23.11.2021).

Informed Consent: Retrospective study.

Peer-review: Externally and internally peer-reviewed.

Author Contributions: Concept - B.İ.E., A.M., E.A.; Design - B.İ.E., A.M., E.A., D.Ö.; Data Collection and/or Processing - B.İ.E., D.Ö.; Analysis and/or Interpretation - A.M.; Literature Search - B.İ.E., D.Ö.; Writing - B.İ.E.

Conflict of Interest: The authors have no conflict of interest to declare.

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

Etik Komite Onayı: Bu çalışma, Sağlık Bilimleri Üniversitesi, Şişli Hamidiye Etfal Eğitim ve Araştırma Hastanesi Sağlık Uygulama ve Araştırma Merkezi Klinik Araştırmalar Etik Kurulu tarafından onaylandı (karar no: 1937, tarih: 23.11.2021).

Hasta Onamı: Retrospektif çalışma.

Hakem Değerlendirmesi: Editörler kurulu ve editörler kurulu dışında olan kişiler tarafından değerlendirilmiştir.

Yazar Katkıları: Konsept - B.İ.E., A.M., E.A.; Dizayn - B.İ.E., A.M., E.A., D.Ö.; Veri Toplama veya İşleme - B.İ.E., D.Ö.; Analiz veya Yorumlama - A.M.; Literatür Arama - B.İ.E., D.Ö.; Yazan - B.İ.E.

Çıkar Çatışması: Yazarlar tarafından çıkar çatışması bildirilmemiştir.

Finansal Destek: Yazarlar tarafından finansal destek almadıkları bildirilmiştir.

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