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$S_1Q_3T_3$ as a prognostic marker in acute pulmonary embolism: Insights from the emergency department

Akut pulmoner embolide prognostik bir belirteç olarak $S_1Q_3T_3$: Acil servisten görüşler

Bahar Işık[1*], İrem Ateş[2], Halil İbrahim Tanrıseven[3], Handan Aksoy[4], Ömer Faruk Solgun[5]

[1] *Erzincan Binali Yıldırım University, Faculty of Medicine, Department of Emergency Medicine, Erzincan, Türkiye*
[2] *Atatürk University, Faculty of Medicine, Department of Anesthesiology and Reanimation, Erzurum, Türkiye*
[3] *Erzincan Binali Yıldırım University, Faculty of Medicine, Department of Cardiology, Erzincan, Türkiye*
[4] *Celal Bayar University, Faculty of Medicine, Department of Chest Diseases, Manisa, Türkiye*
[5] *Kula State Hospital, Department of Emergency Medicine, Manisa, Türkiye*

*0000-0002-5379-6677
*0000-0001-9867-5011
*0000-0002-6915-2876
*0000-0001-7656-6332
*0000-0002-2725-6888

**Sorumlu Yazar:*

Bahar Işık
Erzincan Binali Yıldırım University, Faculty of Medicine, Department of Emergency Medicine, Erzincan, Türkiye

e-mail:
drbaharisik7@gmail.com

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ABSTRACT

Aim: Acute pulmonary embolism occurs when a substance traveling through the bloodstream obstructs an artery in the lungs and is associated with electrocardiographic changes such as the $S_1Q_3T_3$ pattern. We aimed to investigate whether this pattern could be used as a predictor of disease severity by evaluating its effect on mortality and prognosis.
Materials and Methods: This prospective observational cohort study included 100 patients diagnosed with acute pulmonary embolism in the emergency department, without prior cardiovascular or pulmonary disease. Patients with and without $S_1Q_3T_3$ pattern on ECG were evaluated using predefined clinical parameters.
Results: A complete $S_1Q_3T_3$ pattern was detected in 26 patients. These patients had higher rates of prolonged ICU stay, mortality, troponin elevation, PESI scores, PESI score >150, and ward admission. Regression analysis showed that the $S_1Q_3T_3$ pattern was significantly associated with ward admission (OR 4.57), ICU stay ≥3 days (OR 3.33), in-hospital mortality (OR 10.00), troponin elevation (OR 6.16), and PESI score >150 (OR 3.11). It increased the risk of concurrent DVT by 4.2-fold and was associated with a 31.835-point increase in PESI score. The pattern was present in 66.66% of deceased patients and in all patients who were dead on arrival.
Conclusion: The presence of complete $S_1Q_3T_3$ pattern may indicate worse prognosis and higher mortality. Its detection may help emergency physicians identify high-risk patients and guide closer monitoring.

Keywords: *Acute pulmonary embolism, Emergency department, $S_1Q_3T_3$ pattern*

ÖZ

Amaç: Akut pulmoner emboli, kan dolaşımı yoluyla gelen bir maddenin akciğerlerdeki bir atardamarı tıkamasıyla oluşur. $S_1Q_3T_3$ paterni gibi EKG değişiklikleriyle ilişkilidir. Çalışmamızda bu paternin mortalite ve prognoz üzerinde ne denli etkili olduğunu belirleyerek, hastalığın şiddetini saptamada bir öngörücü olarak kullanılabilir olup olmadığına ilişkin bir inceleme yapmak istedik.
Gereç ve Yöntemler: Bu prospektif gözlemsel kohort çalışmaya, daha önce kardiyovasküler sistem (KVS) ve pulmoner sistem hastalığı olmayan, acil servisimizde (AS) APE tanısı alan 100 hasta dahil edildi. EKG'sinde $S_1Q_3T_3$ paterni saptanan hastalar belirlenmiş parametreler açısından değerlendirildi.
Bulgular: 26 hastada komplet $S_1Q_3T_3$ paterni saptandı. Bu gruptaki hastalarda yoğun bakımda 3 gün veya daha uzun süre kalma, mortalite, troponin seviyeleri, PESI (Pulmoner emboli şiddet indeksi) skorları ve PESI skoru >150 olma, servise yatış oranı daha yüksekti. Sonuçlarla anlamlı şekilde ilişkili olan parametreler kullanılarak, regresyon analizi yapıldı. $S_1Q_3T_3$ paterni, servise yatış olasılığının (OR 4,57), 3 gün veya daha uzun süre yoğun bakım ünitesi yatışının (OR 3,33), hastane içi ölüm oranının (OR 10,00), troponin yüksekliğinin (OR 6,16) ve PESI skorunun >150 olmasının (OR 3,11) daha yüksek olasılığıyla anlamlı şekilde ilişkiliydi. $S_1Q_3T_3$ paterninin varlığı eş zamanlı DVT riskini 4,2 kat artırdı. Varlığı, PESI skorlarında 31,835 ünitelik bir artışla ilişkilendirildi. Bu patern hastalardan ölen 9 kişinin EKG'lerinde %66,66 oranında, başvuruda exitus kabul edilen 3 kişinin EKG'lerinde ise %100 oranında mevcuttu.
Sonuç: Sadece EKG'de komplet $S_1Q_3T_3$ paterni bulunması bile daha kötü prognoz ve mortalite ile ilişkili olabilir. İlk değerlendirme sırasında bu bulgu, AS hekimlerini dikkatli olmaya ve tedavi stratejilerini belirlerken daha seçici olmaya yönlendirebilir.

Anahtar Kelimeler: *Akut pulmoner emboli, Acil servis, $S_1Q_3T_3$ paterni*

INTRODUCTION

APE is one of the most lethal cardiopulmonary system (CPS) diseases encountered in the Emergency department (ED) and the third most frequently detected cause of CVS mortality (1). Pulmonary thromboembolism (PTE) may develop due to inherited hypercoagulable states or acquired factors such as surgery-related trauma, prolonged immobility, or active malignancy. PTE is often underrecognized, underdiagnosed, and potentially fatal. According to an international registry study, although <5% of adult PTE cases are massive, their mortality may reach 50%. PTE symptoms are nonspecific and overlap with those of other CPS diseases. Suspicion is critical for diagnosis. Certain ECG findings may aid clinicians in considering this diagnosis. EDs are centers where ECG and echocardiogram (ECHO) can be performed simultaneously and promptly during the diagnostic phase of PTE. ECG is an inexpensive, rapidly interpretable, and noninvasive test, and it is one of the first investigations performed in ED patients. No specific ECG pattern is pathognomonic for APE. Sudden pulmonary artery obstruction leads to increased pressure, causing dilatation or myocardial damage, resulting in right ventricular (RV) abnormalities and associated ECG changes. In APE, various abnormal ECG patterns associated with RV abnormalities emerge (2). Dilatation of the right side of the heart causes transverse rotation, displacing the right ventricle anteriorly and the left ventricle posteriorly. This mechanism underlies the aforementioned ECG changes, including the $S_1Q_3T_3$ (Figure 1) pattern (3). Among these, the presence of a complete $S_1Q_3T_3$ pattern is one of the parameters in the 21-point ECG scoring method, which evaluates the severity of pulmonary embolism (PE) with a 2-point value. The $S_1Q_3T_3$ pattern, observed in 10%–20% of cases, may manifest also in incomplete forms in APE (Table 1). Although ECG findings in PTE have been proposed as predictive diagnostic criteria, their utility in prognostic assessment remains controversial. $S_1Q_3T_3$ pattern may assist clinicians in considering the PTE diagnosis earlier (4). Conditions such as pulmonary hypertension, RV infarction, chronic lung disease, pulmonary stenosis, bronchospasm, and pneumothorax can also cause right heart strain and RV dysfunction (5,6). ECG signs of RV strain include precordial T-wave inversion, QR pattern in lead V1, $S_1Q_3T_3$ pattern, and incomplete or complete right bundle branch block (7). The classic $S_1Q_3T_3$ pattern is neither pathognomonic nor a specific finding (8). Sinus tachycardia is present in 40% of PTE patients and most common (1). The $S_1Q_3T_3$ pattern typically emerges within the first few hours of the event in nearly all PTE cases. However, since approximately 10% of PTEs result in sudden death within the first hour, the observed frequency of $S_1Q_3T_3$ is relatively low (9). ECG abnormalities in APE were first described in 1935 by Sylvester McGinn and Paul White. They noted that a significant number of cases exhibited an S wave ≥1.5 mm in amplitude in the lead I, a Q wave ≥1.5 mm in the lead III, and an inverted T-wave in the lead III. These findings collectively suggested a distinct clinical entity (10). They also identified specific deviations in the $S_1Q_3T_3$ complex. The $S_1Q_3T_3$ pattern has a sensitivity of 54% and a specificity of 62% for PTE (11, 12). Spontaneous resolution of ECG changes indicates that the $S_1Q_3T_3$ pattern in PTE patients is not a permanent marker. It is typically transient, short-lived, and resolves within 14 days after symptom onset (13). The reported prevalence of the classic $S_1Q_3T_3$ pattern in PTE ranges from 10% to 50% (14). One study found that only 12% of patients with angiographically confirmed acute PTE exhibited the $S_1Q_3T_3$ pattern on initial ECG (15). PTE severity is classified in four groups. Elevated cardiac troponin, RV dysfunction, and hemodynamic instability are indicators of high-risk PTE. Prognostic tools such as the PESI and CLOT-5 scores are recommended for clinical risk stratification in APE. In light of this information, our ultimate aim in the study is to investigate the effect of the presence of the $S_1Q_3T_3$ pattern on the course of the disease.

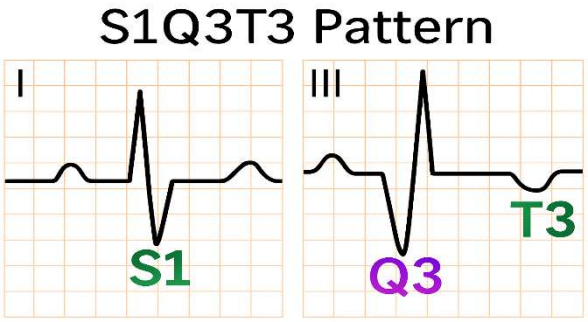

Figure 1. Electrocardiographic $S_1Q_3T_3$ pattern
Characteristic electrocardiographic findings of the $S_1Q_3T_3$ pattern showing a deep S wave in lead I, a Q wave in lead III, and T wave inversion in lead III.

Table 1. Incomplete $S_1Q_3T_3$ patterns and their possible clinical relevance

Incomplete pattern	ECG finding	Possible clinical implication
S_1 only	Prominent S wave in lead I without Q wave or T-wave inversion in lead III	May reflect mild right ventricular strain; nonspecific finding
Q_3 only	Isolated Q wave in lead III	Low specificity; may be incidental; interpret in clinical context
T_3 only	T-wave inversion in lead III without S wave in lead I or Q wave	May indicate early right ventricular strain or nonspecific repolarization abnormality
$S_1 + Q_3$ (no T_3)	S wave in lead I and Q wave in lead III with upright T wave	Intermediate finding; may occur in subclinical or resolving pulmonary embolism

MATERIALS AND METHODS

Approval for this study was obtained from the Erzincan Binali Yıldırım University Scientific Research Ethics Committee (Date: 16.02.2023; Decision No: 2023-04/1). The study was designed as a prospective observational cohort study to investigate the association between electrocardiog raphic

findings and clinical outcomes in patients presenting with APE.

Patients presenting consecutively to the ED with a diagnosis of APE during the predefined study period were enrolled at the time of index ED admission until the target sample size of 100 patients was reached. No selective patient recruitment was performed, and the study population reflects a real-world clinical setting. The sample size is consistent with previous studies in the literature (approximately 80–150 patients) and was considered adequate for statistical analyses. An a priori power analysis demonstrated that, with an alpha error of 5% and a power of 80%, at least 92 patients were required to detect a significant difference in the primary outcome; thus, inclusion of 100 patients fulfilled this requirement.

The baseline time point (time zero) was defined as the ED presentation. All included patients were followed for a fixed period of 30 days after the index visit through hospital electronic medical records to assess clinical outcomes.

Patients aged ≥18 years who were diagnosed with APE within 12 hours of ED presentation and had confirmation of pulmonary embolism by computed tomography pulmonary angiography (CTPA) showing filling defects in the pulmonary arteries were eligible for inclusion. Patients with a history of cardiovascular disease, chronic obstructive pulmonary disease, or hemodynamically significant comorbidities (including cardiogenic pulmonary edema, cardiogenic shock, or acute cor pulmonale) were excluded. Comorbidity data were obtained by reviewing previous medical records and through direct patient interviews. Written informed consent was obtained from all participants. All electrocardiograms (ECGs) were evaluated by a cardiology specialist. Patients who declined clinical follow-up or had non-interpretable or poor-quality ECG recordings were excluded. The first 12-lead ECG obtained in the ED was analyzed. Based on ECG findings, patients were divided into two groups: those with a complete $S_1Q_3T_3$ pattern (Group 1) and those without this pattern (Group 2). The presence of the $S_1Q_3T_3$ pattern was determined according to predefined criteria and guideline-based definitions. Using 12-lead ECG, 26 patients were identified as having a complete $S_1Q_3T_3$ pattern, while 74 patients had other ECG findings. Clinical outcomes assessed during follow-up included hospitalization (ward admission or intensive care unit [ICU] admission), ICU stay longer than 3 days, in-hospital mortality, elevated troponin levels (values >0.04 ng/mL), echocardiographic evidence of right ventricular dysfunction, PESI score, PESI score thresholds (>150 and >200), and extent of vascular involvement. The presence of concurrent deep vein thrombosis (DVT) at the time of diagnosis was recorded and included in the analysis. Patients were followed for 30 days after hospitalization or discharge using electronic medical records. Patients were additionally categorized into five groups according to PESI risk stratification.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were assessed for normality using visual inspection of histograms and the Kolmogorov–Smirnov test. Normally distributed variables are presented as mean ± standard deviation (SD), whereas non-normally distributed variables are expressed as median with interquartile range (IQR). Categorical variables are presented as frequencies and percentages. Comparisons between groups (patients with and without a complete $S_1Q_3T_3$ pattern on ECG) were conducted using the chi-square test or Fisher's exact test for categorical variables, as appropriate. For continuous variables, the independent samples t-test was used for normally distributed data, and the Mann–Whitney U test was applied for non-normally distributed data. To evaluate the association between the presence of the $S_1Q_3T_3$ pattern and adverse clinical outcomes, separate exploratory binary logistic regression models were constructed for each predefined outcome, including presence of DVT, ICU stay ≥3 days, in-hospital mortality, ICU admission, troponin elevation, and PESI score >150. Given the limited number of outcome events, each regression model included only a single independent variable (presence of $S_1Q_3T_3$ pattern) to minimize the risk of model overfitting. Regression results are reported as odds ratios (ORs) with 95% confidence intervals (CIs). Model calibration was assessed using the Hosmer–Lemeshow goodness-of-fit test, and explanatory power was evaluated using Nagelkerke R^2 values. All regression analyses were considered exploratory and interpreted cautiously. For regression analyses, each outcome variable was evaluated separately. ICU admission and ward admission were analyzed as independent binary outcomes. In-hospital mortality included patients who were dead on arrival as well as those who died during hospitalization. Additionally, linear regression analysis was performed to evaluate the relationship between the $S_1Q_3T_3$ pattern and continuous PESI score values. All statistical tests were two-tailed, and a p-value <0.05 was considered statistically significant.

RESULTS

The study included 100 patients (48 males and 52 females) aged 28–99 years. The $S_1Q_3T_3$ pattern was detected in 26 patients. Eighty-three patients were hospitalized. Thirteen patients (13%) were discharged with medication, 37 (37%) were admitted to the ward, and 45 (45%) required ICU admission. Three patients (3%) were dead on arrival at the ED, and 2 patients (2%) refused hospitalization. Embolus localization was at subsegmental in 22 cases, at segmental in 34, at bilateral main pulmonary artery in 27, and at unilateral main pulmonary artery in 17 cases. At the time of diagnosis, concurrent DVT was present in 22 patients. Forty patients required ICU stays >3 days. Nine of the patients died. Three of them were already exitus, and six patients died during the ICU monitoring. $S_1Q_3T_3$ pattern was detected on ECGs of all patients who were brought in deceased. 66.66% of all dead patients had $S_1Q_3T_3$ pattern on their ECG. 21 patients eged 55 years or younger. 15 patients were discharged with medication, 37 were admitted to the ward, 51 had high troponin levels, and 40 exhibited RV dysfunction on ECHO. According to the PESI score, 7 patients were classified as very low risk, 7 as low risk, 22 as intermediate risk, 14 as high risk, and 50 as very high risk. 31 patients had PESI scores >150, and eight had PESI scores >200. (Table 2).

Table 2. Baseline characteristics and clinical outcomes of patients

Variable	Category	n	%
Sex	Male	48	48.0
	Female	52	52.0
$S_1Q_3T_3$ pattern on ECG	No	74	74.0
	Yes	26	26.0
Hospitalization	No	17	17.0
	Yes	83	83.0
Age ≤55 years	No	79	79.0
	Yes	21	21.0
Treatment outcome	Discharge with medication	15	15.0
	Ward admission	37	37.0
	ICU admission	48	48.0
In-hospital mortality	No	91	91.0
	Yes	9	9.0
Pulmonary embolism localization	Subsegmental	22	22.0
	Segmental	34	34.0
	Unilateral main pulmonary artery	17	17.0
	Bilateral main pulmonary arteries	27	27.0
PESI risk class	Very low (<65)	7	7.0
	Low (66–85)	7	7.0
	Moderate (86–105)	22	22.0
	High (106–125)	14	14.0
	Very high (>125)	50	50.0
PESI score >150	No	69	69.0
	Yes	31	31.0
PESI score >200	No	92	92.0
	Yes	8	8.0
Right ventricular dysfunction on ECHO	No	19	19.0
	Yes	40	40.0
	Not available	41	41.0
Presence of DVT	No	78	78.0
	Yes	22	22.0
Troponin elevation	No	49	49.0
	Yes	51	51.0

Abbreviations: ECG, electrocardiography; ICU, intensive care unit; PESI, Pulmonary Embolism Severity Index; ECHO, echocardiography; DVT, deep vein thrombosis.

The overall median PESI score was 125.5 (IQR 92–168). The median ICU and ward length of stay were 9 (IQR 6–13) and 6 (IQR 4–8) days, respectively. (Table 3) The association between the $S_1Q_3T_3$ pattern and age 55 years, PESI score, length of ICU hospitalization (days), and length of ward hospitalization (days) was analyzed. Accordingly, patients with the $S_1Q_3T_3$ pattern had higher PESI scores than those without. (Table 4).

Table 3. Descriptive statistics of continuous variables

Variable	Value
Age (years)†	71.92 ± 15.34
PESI score‡	125.5 (92–168)
ICU length of stay (days)‡	9 (6–13)
Ward length of stay (days)‡	6 (4–8)

Statistical tests: † Normally distributed variable, presented as mean ± standard deviation (SD).
‡ Non-normally distributed variables, presented as median (interquartile range, IQR).
Abbreviations: ICU, intensive care unit; PESI, Pulmonary Embolism Severity Index.

Table 4. Comparison of clinical characteristics according to the presence of $S_1Q_3T_3$ pattern

Variable	Category	$S_1Q_3T_3$ (+) n (%)	$S_1Q_3T_3$ (–) n (%)	p-value
Sex	Male	13 (27.1)	35 (72.9)	0.812
	Female	13 (25.0)	39 (75.0)	
Age ≤55 years	Yes	7 (33.3)	14 (66.7)	0.389
	No	19 (24.1)	60 (75.9)	
Pulmonary embolism localization	Subsegmental	4 (18.2)	18 (81.8)	0.680
	Segmental	9 (26.5)	25 (73.5)	
	Unilateral main PA	4 (23.5)	13 (76.5)	
	Bilateral main PA	9 (33.3)	18 (66.7)	
Presence of DVT	Yes	11 (50.0)	11 (50.0)	**0.004**
	No	15 (19.2)	63 (80.8)	
Troponin elevation	Yes	21 (41.2)	30 (58.8)	**<0.001**
	No	5 (10.2)	44 (89.8)	
ICU stay ≥3 days or in-hospital mortality	Yes	16 (40.0)	24 (60.0)	**0.009**
	No	10 (16.7)	50 (83.3)	
Treatment outcome	Discharge with medication	1 (6.7)	14 (93.3)	**0.002**
	Ward admission	5 (13.5)	32 (86.5)	
	ICU admission or mortality	20 (41.7)	28 (58.3)	
PESI score >150	Yes	13 (41.9)	18 (58.1)	**0.015**
	No	13 (18.8)	56 (81.2)	

Statistical tests: Chi-square or Fisher's exact test, as appropriate.
Abbreviations: PA, pulmonary artery; ICU, intensive care unit; PESI, Pulmonary Embolism Severity Index; DVT, deep vein thrombosis.

A significant association was found between the $S_1Q_3T_3$ pattern and the mean PESI score. (Table 5). Patients with the $S_1Q_3T_3$ pattern had higher PESI scores compared to those without. The presence of the $S_1Q_3T_3$ pattern was more common in patients with a PESI score >150 and elevated troponin levels compared to those without. Regression analysis was performed on parameters significantly associated with the $S_1Q_3T_3$ pattern. Exploratory regression analyses demonstrated significant associations between the $S_1Q_3T_3$ pattern and adverse clinical outcomes. The presence of the $S_1Q_3T_3$ pattern was associated with higher odds of deep vein thrombosis (OR 4.20, 95% CI 1.53–11.51) and ICU stay ≥3 days (OR 3.33, 95% CI 1.32–8.43). It was also associated with higher odds of in-hospital mortality (OR 10.00, 95% CI 1.21–82.35). In addition, the $S_1Q_3T_3$ pattern was significantly associated with ward admission (OR 4.57, 95% CI 1.52–13.78), troponin elevation (OR 6.16, 95% CI 2.09–18.14), and PESI score >150 (OR 3.11, 95% CI 1.22–7.92). Additionally, the $S_1Q_3T_3$ pattern on ECG was associated with an increase of 31.84 points in PESI score ($\beta = 31.84$) (Table 6).

Table 5. Comparison of continuous variables according to the presence of $S_1Q_3T_3$ pattern

Variable	$S_1Q_3T_3$ (–)	$S_1Q_3T_3$ (+)	p-value
Age (years)†	72.46 ± 15.66	70.38 ± 14.59	0.439
PESI score‡	116 (92–158)	148.5 (118–192)	0.003
ICU length of stay (days)‡	8 (6–12)	10 (7–14)	0.466
Ward length of stay (days)‡	6 (4–8)	6 (4–9)	0.618

Statistical tests: † Compared using independent samples t-test, ‡ Compared using Mann–Whitney U test.
Abbreviations: ICU, intensive care unit; PESI, Pulmonary Embolism Severity Index.

Table 6. Association between the $S_1Q_3T_3$ pattern and clinical outcomes (exploratory regression analyses)

Outcome	Effect estimate	95% CI	p-value
Presence of DVT	OR 4.20	1.53–11.51	0.005
ICU stay ≥3 days	OR 3.33	1.32–8.43	0.011
In-hospital mortality	OR 10.00	1.21–82.35	0.032
Ward admission	OR 4.57	1.52–13.78	0.007
Troponin elevation	OR 6.16	2.09–18.14	0.001
PESI score >150	OR 3.11	1.22–7.92	0.017
PESI score (continuous)	β = +31.84	10.85–52.83	0.003

Statistical tests: Each outcome was analyzed in a separate regression model. Binary outcomes were evaluated using logistic regression and are reported as odds ratios (ORs). Continuous PESI score was evaluated using linear regression and is reported as β coefficient.
Abbreviations: CI: confidence interval; DVT: deep vein thrombosis; ICU: intensive care unit; PESI: Pulmonary Embolism Severity Index.

DISCUSSION

The $S_1Q_3T_3$ pattern on ECG is primarily regarded as a diagnostic marker for APE but has been less emphasized in prognostic and mortality assessments. It is well established that this pattern is more prevalent in massive emboli than in smaller ones and is thus associated with poorer prognosis. The present study aimed to quantify this association more definitively. Furthermore, we focused specifically on the prognostic impact of the complete $S_1Q_3T_3$ pattern within the broader ECG scoring system for APE. A similar study by Jaff et al. demonstrated that the $S_1Q_3T_3$ pattern is associated with a worse short-term prognosis in APE (16). Devesa et al. reported that the presence of $S_1Q_3T_3$ serves as an indicator of RV involvement in acute cor pulmonale and as a predictor of RV dysfunction, suggesting its use as an indirect marker for risk stratification in APE cases (17,19). Kukla et al. emphasized that the classic McGinn-White sign reflects higher disease severity rather than directly predicting mortality (18). Shopp et al. reported that 16.6% of ECG findings predictive of hemodynamic collapse or death within 30 days of APE included the $S_1Q_3T_3$ pattern (8). Supporting this, Nampoothiri et al. found that the pattern was associated with severe clinical progression and higher mortality in PTE (20). Most studies determining case outcomes in APE are retrospective (21). In a prospective multicenter study, Weekes et al. investigated the association of early ECG patterns with clinical deterioration in PTE. SVT, in particular, was significantly more frequent in those who deteriorated and was considered an independent predictor of subsequent clinical worsening. Sheikh et al. found that the presence of $S_1Q_3T_3$ on ECG was associated with longer hospital stays (22). The amplitude of the T-wave in lead II can be a simple and useful discriminator for patients with severe PTE (23). Our study also supported all these findings. In the present study, the $S_1Q_3T_3$ pattern was more frequent in patients aged <55 years and those with concomitant DVT at diagnosis. Although increasing age is associated with a worse prognosis according to PESI, in our cohort, the $S_1Q_3T_3$ pattern was present in 33.3% of patients aged <55 years, exceeding the rate in those aged >55 years. DVT, observed in 30%–50% of PTE cases, is associated with higher early mortality risk, particularly when proximal (24). Consistent with this, the present study found a higher incidence of DVT in patients with the $S_1Q_3T_3$ pattern. Accurate risk stratification is essential to properly manage PTE treatment. Therefore, in addition to establishing a diagnosis, clinicians must determine patient management strategies and the optimal treatment to initiate based on these risk classifications. They serve as a guide for selecting therapeutic approaches. In patients with high or intermediate-high-risk PTE, anticoagulation should be started even during the diagnostic workup. Thrombolysis is preferred in high-risk APE or in intermediate-risk patients receiving anticoagulation who exhibit hemodynamic deterioration. In carefully selected low-risk APE patients, early discharge with outpatient continuation of therapy is recommended. In patients with APE, the isolated presence of the $S_1Q_3T_3$ pattern on ECG has limited prognostic value. However, when $S_1Q_3T_3$ occurs in conjunction with right ventricular dysfunction on echocardiography or CT and elevated cardiac biomarkers (e.g., troponin), the patient should be considered at intermediate-high risk, warranting close monitoring and timely consideration of reperfusion or catheter-directed therapies in the event of clinical deterioration. Since current evidence does not support this approach and more comprehensive studies are needed, treatment decisions—whether anticoagulation alone, systemic thrombolysis, or catheter-based intervention—are determined by hemodynamic status, imaging of right ventricular function, and biomarker results integrated with validated risk scores. Thus, electrocardiographic abnormalities such as $S_1Q_3T_3$ provide supportive prognostic information but cannot independently direct therapy (25), but $S_1Q_3T_3$ and related ECG features are associated with in-hospital mortality (26). In our study the wide confidence interval in the mortality model reflects the limited number of events and should be interpreted cautiously.

Limitations

Since APE is not a frequently encountered condition and patients with preexisting diseases were not included in the study, the number of cases remained limited. The $S_1Q_3T_3$ positive group is small, so the analysis power is limited. A multicenter study with a larger cohort could yield more robust conclusions. While patients with preexisting diseases were excluded, undiagnosed or undocumented cases may have

influenced the results. Another limitation of the study is the lack of longer-term patient follow-up.

CONCLUSION

When evaluating the risk score it should be noted that the presence of the $S_1Q_3T_3$ pattern is significantly associated with ICU admission, mortality, and higher PESI scores. Based on these findings, especially in resource-poor settings, the $S_1Q_3T_3$ pattern can be considered during preliminary assessment and in decisions regarding further diagnostic evaluation for prognostic assessment, according to current data, and may contribute to early risk stratification in the emergency department but should not independently guide treatment decisions. When an ED physician identifies an $S_1Q_3T_3$ pattern, this finding may prompt greater caution in risk stratification and emphasize the need for closer clinical monitoring, rather than directly guiding treatment. However, the presence of $S_1Q_3T_3$ should not lead to unnecessarily risky treatment decisions. These findings suggest that the $S_1Q_3T_3$ pattern may reflect increased disease severity rather than directly influencing treatment decisions.

Ethical Approval

Ethical approval for this study was obtained from the Erzincan Binali Yıldırım University Scientific Research Ethics Committee (Date: 16.02.2023; Decision No: 2023-04/1).

Conflict of Interest

The authors declare that they have no conflicts of interest related to this study.

Financial Disclosure

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Authors' Contributions

Concept and design: BI, İA, Data collection: BI, HA, ÖFS, Data analysis: BI, HİT, Manuscript drafting: BI, Critical revision: All authors, Final approval: All authors.

Data Sharing Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, artificial intelligence tools were used only for language editing purposes. The authors take full responsibility for the content.

REFERENCES

1. Konstantinides SV, Meyer G, Becattini C, et al. 2019 ESC Guidelines for the diagnosis and management of acute pulmonary embolism developed in collaboration with the European Respiratory Society (ERS). *Eur Heart J.* 2020;41(4):543-603. https://doi.org/10.1093/eurheartj/ehz405
2. Digby GC, Kukla P, Zhan ZQ, et al. The value of electrocardiographic abnormalities in the prognosis of pulmonary embolism: A consensus paper. Ann Noninvasive Electrocardiol. 2015;20(3):207-23. https://doi.org/10.1111/anec.12278
3. Mercer M, Patel K. Electrocardiographic findings in pulmonary emboli. Curr Emerg Hosp Med Rep. 2015;3(2):109-12. https://doi.org/10.1007/s40138-015-0075-9
4. Petruzzelli S, Palla A, Pieraccini F, Donnamaria V, Giuntini C. Routine electrocardiography in screening for pulmonary embolism. Respiration. 1986;50(4):233-43. https://doi.org/10.1159/000194933
5. Stein PD, Matta F, Sabra MJ, et al. Relation of electrocardiographic changes in pulmonary embolism to right ventricular enlargement. Am J Cardiol. 2013;112(12):1958-61. https://doi.org/10.1016/j.amjcard.2013.08.030
6. Weekes AJ, Raper JD, Thomas AM, et al. Electrocardiographic findings associated with early clinical deterioration in acute pulmonary embolism. Acad Emerg Med. 2022;29(10):1185-96. https://doi.org/10.1111/acem.14554
7. Thomson D, Kourounis G, Trenear R, et al. ECG in suspected pulmonary embolism. Postgrad Med J. 2019;95(1119):12-7. https://doi.org/10.1136/postgradmedj-2018-136178
8. Shopp JD, Stewart LK, Emmett TW, Kline JA. Findings from 12-lead electrocardiography that predict circulatory shock from pulmonary embolism: Systematic review and meta-analysis. Acad Emerg Med. 2015;22(10):1127-37. https://doi.org/10.1111/acem.12769
9. Adhikari CM, Bishal KC, Khadka S. Clinical profile, management and outcome of pulmonary embolism in Shahid Gangalal National Heart Centre, Kathmandu, Nepal. Egypt Heart J. 2018;70(1):41-43. https://doi.org/10.1016/j.ehj.2017.06.001
10. McGinn S, White PD. Acute cor pulmonale resulting from pulmonary embolism. JAMA. 1935;104(17):1473-80. https://doi.org/10.1001/jama.1935.02760170011004
11. Ferrari E, Imbert A, Chevalier T, Mihoubi A, Morand P, Baudouy M. The ECG in pulmonary embolism: Predictive value of negative T waves in precordial leads—80 case reports. Chest. 1997;111(3):537-43. https://doi.org/10.1378/chest.111.3.537
12. Rodger M, Makropoulos D, Turek M, et al. Diagnostic value of the electrocardiogram in suspected pulmonary embolism. Am J Cardiol. 2000;86(7):807-9. https://doi.org/10.1016/S0002-9149(00)01093-1
13. Nielsen TT, Lund O, Rønne K, Schifter S. Changing electrocardiographic findings in pulmonary embolism in relation to vascular obstruction. Cardiology. 1989;76(4):274-84. https://doi.org/10.1159/000174510

14. Chan TC, Vilke GM, Pollack M, Brady WJ. Electrocardiographic manifestations: pulmonary embolism. *J Emerg Med*. 2001;21(3):263-270. https://doi.org/10.1016/s0736-4679(01)00389-4
15. Ullman E, Brady WJ, Perron AD, Chan T, Mattu A. Electrocardiographic manifestations of pulmonary embolism. Am J Emerg Med. 2001;19(6):514-9. https://doi.org/10.1053/ajem.2001.27172
16. Jaff MR, McMurtry MS, Archer SL et al. Management of massive and submassive pulmonary embolism, iliofemoral deep vein thrombosis, and chronic thromboembolic pulmonary hypertension: A scientific statement from the American Heart Association. Circulation. 2011;123(16):1788-1830. https://doi.org/10.1161/CIR.0b013e318214914f
17. Devesa A, Rivero AL, Romero-Daza AM, et al. Electrocardiographic changes as a predictor of right ventricular dysfunction in acute pulmonary embolism. Circulation. 2017;136(Suppl 1):A18323.
18. Kukla P, Długopolski R, Krupa E, Furtak R, Wrabec K, Szełemej R. The value of ECG parameters in estimating myocardial injury and establishing prognosis in patients with acute pulmonary embolism. Kardiol Pol. 2011;69(9):933-938. https://doi.org/10.5603/KP.2011.0186
19. Boey E, Teo SG, Poh KK. Electrocardiographic findings in pulmonary embolism. Singapore Med J. 2015;56(10):533-7. https://doi.org/10.11622/smedj.2015147
20. Nampoothiri RV, Lakshman A, Bhalla A, Varma S. ECG in evaluation for pulmonary thromboembolism: Occam's razor or Hickam's dictum? J Clin Diagn Res. 2016;10(5):OJ01. https://doi.org/10.7860/JCDR/2016/16877.7872
21. Qaddoura A, Digby GC, Kabali C, Kukla P, Zhan ZQ, Baranchuk AM. The value of electrocardiography in prognosticating clinical deterioration and mortality in acute pulmonary embolism: A systematic review and meta-analysis. Clin Cardiol. 2017;40(10):814-824. https://doi.org/10.1002/clc.22742
22. Sheikh AR, Mantoo S, Shah S, Hamid Wani RU, Wani SN. Predictors of prolonged hospital stay in patients with acute pulmonary thromboembolism: A hospital-based cohort study. J Assoc Physicians India. 2022;70(5):11-12.
23. Yoon NS, Cho JG, Park HW, Hwang GS, Kim YJ, Kim KB. Usefulness of the 12-lead electrocardiography in the diagnosis and evaluation of severity of pulmonary thromboembolism. Korean Circ J. 2005;35(5):389-95. https://doi.org/10.4070/kcj.2005.35.5.389
24. Wendelboe AM, Raskob GE. Global burden of thrombosis: Epidemiologic aspects. Circ Res. 2016;118(9):1340-1347. https://doi.org/10.1161/CIRCRESAHA.115.306841
25. Jiao S, Liu Y, He H, et al. ECG abnormalities and biomarkers enable rapid risk stratification in normotensive patients with acute pulmonary embolism. Clin Respir J. 2025;19(6):e70060. https://doi.org/10.1111/crj.70060
26. Yan XX, Zhang HD, Peng FH, et al. Prognostic significance of quantitative electrocardiographic parameters in patients with non-high-risk pulmonary embolism. Eur J Intern Med. 2024;120:46-51. https://doi.org/10.1016/j.ejim.2023.08.028