

ECG changes in acute pulmonary embolism

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ECG changes in APE are related to dilation of the right atrium and right ventricle with consequent shift in the position of the heart, Right ventricular ischaemia, Increased stimulation of the sympathetic nervous system due to pain, anxiety and hypoxia

1. **Rhythm** Sinus or atrial fibrillation are frequent, atrial flutter, or atrial tachycardia (8%)
2. **Heart rate:** Sinus tachycardia present in approximately 45% of cases
3. **Right atrial enlargement (P pulmonale pattern)** – peaked P wave in lead II > 2.5 mm in height (9%)
4. **QRS axis:** Right axis deviation observed in »16% of cases. Extreme right axis deviation may occur, with axis between 0° and -90°, giving the appearance of left axis deviation (“pseudo left axis”)
5. **Complete or incomplete R BB (18%)**

6. A longer RS time in inferolateral leads can be a very useful index for diagnosing acute PE as well as for estimating the RV end-diastolic diameter and Systolic Pulmonary Artery Pressure (SPAP). The ROC curve analyses revealed that the cut-off value of RS time for predicting acute PE was 64.20 ms with a sensitivity of 85.3% and a specificity of 79.4% (AUC: 0.846, 95%CI: 0.749-0.944; $p < 0.001$). In the correlation analyses; the RS time was correlated with RV end-diastolic diameter ($r = 0.422$; $p < 0.001$), RV/left ventricle (LV) ratio ($r = 0.622$; $p < 0.001$), and systolic pulmonary artery pressure (SPAP) ($r = 0.508$; $p < 0.001$).
(Ibrahim Rencuzogullari 1, Metin Çağdaş 2, Yavuz Karabağ 2, Süleyman Karakoyun 2, Handan Çiftçi 3, Mustafa Ozan Gürsoy 4, Sibel Karayol 5, Tufan Çinar 6, Ozan Tanik 7, Şerif Hamideyin 2. A novel ECG parameter for diagnosis of acute pulmonary embolism: RS time: RS time in acute pulmonary embolism Am J Emerg Med. 2019 Jul;37(7):1230-1236. doi: 10.1016/j.ajem.2018.09.010.)

7. Right ventricular strain pattern – T wave inversions in the right precordial leads (V1-4) $\pm$ the inferior leads (II, III, aVF). This pattern is associated with high pulmonary artery pressures (34%)

8. T wave inversion in leads V1-4 and ST segment elevation or depression (Sukhija R, Aronow W, Ahn C, Kakar P. Electrocardiographic abnormalities in patients with right ventricular dilation due to acute pulmonary embolism. *Cardiology*. 2006; 105:57–60. 2006;105(1):57-60. doi: 10.1159/000089249.)

9. ST-segment elevation in V₁ and aVR,

10. T-wave inversion in leads V1 to V3 had the greatest sensitivity and diagnostic accuracy for identifying RV dysfunction in patients with Acute PE.

(Gopikrishna Punukollu 1, Ramesh M Gowda, Balendu C Vasavada, Ijaz A Khan. Role of electrocardiography in identifying right ventricular dysfunction in acute pulmonary embolism Am J Cardiol. 2005 Aug 1;96(3):450-2. doi: 10.1016/j.amjcard.2005.03.099.)

11. Dominant R wave in V1 – a manifestation of acute right ventricular dilatation

12. S1 QIII TIII pattern/S₁Q₃T₃ – deep S wave in lead I, Q wave in III, inverted T wave in III (20%). This “classic” finding is neither sensitive nor specific for PE. The classic S1Q3T3 pattern, was first described by McGinn and White in 1935 (McGinn S, White PD. Acute cor pulmonale resulting from pulmonary embolism. JAMA. 1935;104(17):1473-1480. doi:10.1001/jama.1935.02760170011004).

The McGinn-White Sign is the S1Q3T3 pattern seen on the ECG in the setting of acute pulmonary embolism or other causes of acute right heart strain (cor pulmonale). A large S wave in lead I, a Q wave in lead III and an inverted T wave in lead III together indicate acute right heart strain.

This pattern only occurs in about 10% of people with pulmonary embolisms and is similar to the ECG findings of a left posterior fascicular block, (LPFB).

Recall that sinus tachycardia is actually the most common ECG finding during a pulmonary embolus.

13. Clockwise rotation – shift of the R/S transition point towards V6 with a persistent S wave in V6 (“pulmonary disease pattern”), implying rotation of the heart due to right ventricular dilatation. When the transition on precordial leads (R=S) occurs after V4, this is called clockwise rotation (CWR). Possible causes of clockwise rotation are: intraventricular conduction abnormalities secondary to myocardial degeneration, right ventricular heart disease, shift of the septum to the left, dilated cardiomyopathy, shift of the whole heart, pulmonary emphysema, vertical heart (usually thin and tall persons) and pulmonary embolism (Tahara Y, Mizuno H, Ono A, and Ishikawa K. Evaluation of the electrocardiographic transitional zone by cardiac computed tomography. J Electrocardiol. 1991 Jul;24(3): 239-45. DOI:10.1016/0022-0736(91)90029-I)

14. Concomitant T wave inversions in the inferior (II, III, aVF) and right precordial leads (V1-4) is the most specific finding in favor of PE, with reported specificities of up to 99% in one study.

15. Non-specific ST segment and T wave changes, including ST elevation and depression (50%):

Differential diagnosis with acute coronary syndrome (ACS)

Negative T waves in leads III and V1 were observed in only 1% of patients with ACS compared with 88% of patients with Acute PE (p less than 0.001). The sensitivity, specificity, positive predictive value, and negative predictive value of this finding for the diagnosis of PE were 88%, 99%, 97%, and 95%, respectively. In conclusion, the presence of negative T waves in both leads III and V1 allows PE to be differentiated simply but accurately from ACS in patients with negative T waves in the precordial leads.

Masami Kosuge, MD Kazuo Kimura, MD. Toshiyuki Ishikawa, MD. Toshiaki Ebina, MD. Kiyoshi Hibi, MD. Ikuyoshi Kusama, MD. Tatuya Nakachi, MD. Mitsuaki Endo, MD. Naohiro Komura. MD. Satoshi Umemura, MD. *Electrocardiographic Differentiation Between Acute Pulmonary Embolism and Acute Coronary Syndromes on the Basis of Negative T Waves. Am J Cardiol . 2007 Mar 15;99(6):817-21. doi: 10.1016/j.amjcard.2006.10.043*

An ECG scoring system may potentially be useful in identifying patients at high risk of increased hospital morbidity and mortality from acute PE. ECG and echocardiography of 159 patients with a diagnosis of acute PE using ventilation/perfusion scan or spiral computed tomographic scan at 2 Emory-affiliated hospitals were reviewed. The 21-ECG score was compared with the presence or absence of RV dysfunction and the 2 major end points of complicated in-hospital course or death.

ECG score was significantly higher in patients with RV dysfunction (p 3 could predict RV dysfunction with sensitivity, specificity, and positive and negative predictive values of 76%, 82%, 76%, and 86%, respectively. An ECG score >3 could predict a complicated in-hospital course and mortality with sensitivities of 58% and 59%, specificities of 60% and 58%, positive predictive values of 16% and 10%, and negative predictive values of 89% and 95%, respectively.

In conclusion, the 21-ECG scoring system can predict RV dysfunction in patients with acute PE well. However; its ability to predict an adverse in-hospital course is limited.

The 21- ECG score

Characteristics	Score
Tachycardia (>100 beats/min)	2
Incomplete right branch bundle block*	2
Complete right branch bundle block†	3
S wave in lead I‡	0
Q wave in lead III§	1
Inverted T wave in lead III	1
If all of S1-Q3-T3	2
T-wave inversion in leads V1–V4 #	4
T-wave inversion in lead V1 (mm)	0
<1	1

1-2	2
>2	
T-wave inversion in lead V2 (mm)	1
<1	2
1-2	3
>2	
T-wave inversion in lead V3 (mm)	1
<1	2
1-2	3
>2	

ECG total score (maximum 21)

* QRS complex of 0.10 to 0.11 and S wave in lead I and terminal R wave in lead V1 >1.5 mm.

† QRS >0.11 seconds and S wave in lead I and terminal R wave in lead V1 >1.5 mm.

‡ First negative deflection after a R wave >1.5 mm.

§ First negative deflection after the P wave and before any R wave >1.5 mm. S wave in lead I >1.5 mm, Q in lead III >1.5 mm associated with negative T wave in lead III.

Pointed and symmetrical inverted T wave from leads V1 to V4.

Clinical Usefulness

The ECG is neither sensitive nor specific enough to diagnose or exclude PE

Around 18% of patients with PE will have a completely normal ECG.

However, with a compatible clinical picture (sudden onset pleuritic chest pain, hypoxia), an ECG showing new RAD, RBBB or T-wave inversions may raise the suspicion of PE and prompt further diagnostic testing

In patients with radiologically confirmed PE, there is evidence to suggest that ECG changes of right heart strain and RBBB are predictive of more severe pulmonary hypertension; while the resolution of anterior T-wave inversion has been identified as a possible marker of pulmonary reperfusion following thrombolysis

Differential Diagnosis

The ECG changes described above are not unique to PE. A similar spectrum of ECG changes may be seen with any cause of acute or chronic cor pulmonale (i.e. any disease that causes right ventricular strain / hypertrophy due to hypoxic pulmonary vasoconstriction).

Acute cor pulmonale:

Severe pneumonia

Exacerbation of COPD / asthma

Pneumothorax

Recent pneumonectomy

Upper airway obstruction

Chronic cor pulmonale:

Chronic obstructive pulmonary disease
Recurrent small PEs
Cystic fibrosis
Interstitial lung disease
Severe kyphoscoliosis
Obstructive sleep apnea

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Recurrent small PEs

