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Original Contribution

The electrocardiographic characteristics of an acute embolism in the pulmonary trunk and the main pulmonary arteries☆

Jinghua Zhang, MD*, Guizhi Liu, MD, Suifeng Wang, MM, Weiguo Du, MB, Peisheng Lv, MB, Hua Guo, MM, Qian Sun, MB, Yining Liu, MB, Xinxin Qi, MB

Department of Cardiovasology, First Affiliated Hospital of Zhengzhou University, Zhengzhou, Henan province, China

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ABSTRACT

Objective: Pulmonary embolism (PE) is a common cardiovascular disease that can be easily missed or misdiagnosed. Electrocardiogram (ECG) is valuable in making early diagnoses and performing risk stratification with regard to acute PE.

Methods: A total of 147 hospitalized patients diagnosed with acute PE were enrolled in this study and divided into the following 2 groups: main pulmonary artery trunk or main pulmonary artery (MPA) embolism and lobar artery or remote branch embolism. Electrocardiographic abnormalities associated with acute PE were subsequently identified.

Results: Electrocardiographic abnormalities were significantly different between the pulmonary trunk/MPA embolism group and the lobar artery/remote branch embolism group. The incidence of pulmonary trunk/MPA emboli was significantly related to the number of ECG abnormalities ($t = -7.086$, $P = 5.556e\text{-}11$). Furthermore, the number of ECG abnormalities noted among patients with pulmonary trunk/MPA emboli was 5.276 times greater than the number observed among the lobar artery/remote branch embolism group ($P < .001$, 95% confidence interval $= -6.57$ to 3.97). The risk of either moderate or severe right ventricular hypertrophy was increased by 16.18% among patients with either pulmonary trunk or MPA emboli compared with patients with either lobar artery or remote branch emboli ($P < .001$, 95% confidence interval $= -2.76$ to 0.876). The correct classification rate was as high as 92.3% when ECG was used to classify the prognosis of PE patients.

Conclusions: The number of ECG abnormalities and the degree of right ventricular hypertrophy as determined via ECG can be used to assess the probability of developing a PE in the pulmonary trunk and MPA. Furthermore, ECGs can assist clinicians with risk stratification.

1. Introduction

Pulmonary embolism (PE) is a common cardiovascular disease that can be easily missed or misdiagnosed. An embolus can be composed of various substances, including thrombus, fat, air, bone marrow, amniotic fluid, and septic material. Emboli most commonly originate from thrombi in the deep veins of the lower extremities.

Because of the sizes of emboli and their positions, severities, rates of occurrence, and the presence of underlying cardiac or pulmonary disease, both the clinical manifestations and the mortality associated with PE can vary. Although smaller emboli can be free of clinical symptoms, larger emboli can cause dyspnea, cyanosis, syncope, or sudden death.

The mortality rate of an untreated acute PE is 30% but can be reduced to 2%-8% following an early diagnosis and sufficient treatment [1]. As a cost-effective and clinically effective measure, the electrocardiogram (ECG) is valuable in assisting clinicians in making early diagnoses and performing risk stratification with regard to acute PE [2,3].

2. Methods

2.1. Participants

A total of 147 hospitalized patients diagnosed with acute PE via spiral computed tomography pulmonary angiography (CTPA) were enrolled between March 2011 and April 2014. Electrocardiogram and CTPA were performed on all patients within 24 hours following the onset of PE. The patients were divided into the following groups based on whether the emboli were located in the pulmonary trunk or the main pulmonary arteries (MPAs): the main pulmonary artery trunk or MPA embolism group and the lobar artery or remote branch embolism group.

2.2. ECG evaluation

Twelve-lead ECGs were recorded upon admission at a paper speed of 25 mm/s and an amplification of 10 mm/mV. The following ECG

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* Corresponding author. Tel.: +86 13837199122.
E-mail address: 13837199122@163.com (J. Zhang).

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abnormalities associated with acute PE were subsequently identified: (1) SIQIIITIII; (2) complete or incomplete right bundle-branch block (RBBB); (3) peripheral low voltage; (4) sinus tachycardia; (5) atrial arrhythmia; (6) prolonged QTc interval; (7) right ventricular hypertrophy (RVH); (8) negative T waves (NTWs) in leads III, aVF, and V1 to V3/V4; (9) the number of NTWs; (10) ST-segment depression (STD) in leads V1 to V6; (11) ST-segment elevation (STE) in leads aVR, III, and V1-V3/V4; and (12) PR segment depression in lead V1. *SIQIIITIII* was defined as the presence of an S wave in lead I and a Q wave in lead III, each with an amplitude ≥1.5 mm and an NTW in lead III. *Complete* or *incomplete RBBB* was defined using conventional criteria. *Peripheral low voltage* was defined as the greatest overall deflection of the QRS complex ≤5 mm in all limb leads. *Sinus tachycardia* was defined as an increase in sinus rhythm >100 beats per minute. Negative T waves were considered present if the depth was >0.5 mm in any lead except for either the aVR or aVL lead. Atrial arrhythmia included premature atrial beats, atrial flutter, and atrial fibrillation; a *prolonged QTC interval* was defined as a QTc ≥440 milliseconds. The standards for the diagnosis of RVH were as follows: Mild, 1 = the QRS axis exhibits slight right-sided deviation, 2 = lead V1 has either an rS or an rsR' pattern, lead V5 has either an RS or an Rs pattern, or all leads from V1 to V6 have either an rS or QS pattern; moderate, 1 = the QRS axis exhibits moderate right-sided deviation, 2 = lead V1 has either an Rs or an RS pattern, and the leads from V4 to V6 have either an RS or an Rs pattern; and severe, 1 = the QRS axis exhibits severe right-sided deviation, 2 = lead V1 has either a qR or R pattern, and the leads from V4 to V6 have either an rS or a QS pattern.

2.3. Collection of clinical data

A total of 147 patients were selected, 99 patients accepted the ultrasonic examination to measure the right ventricular end-diastolic diameter (RVEDD), and 89 patients accepted the ultrasonic examination to measure the pulmonary arterial pressure. The plasma levels of Brain Natriuretic Peptide (BNP) and Cardiac Troponin T (cTNT) were measured in 65 and 70 patients, respectively. An RVEDD >20 mm was used to define an *increased right ventricular end-diastolic diameter*. A BNP >500 ng/L and a cTNT >0.01 μg/L were considered abnormal.

2.4. Statistical analyses

We analyzed the data using R3.13. We applied the Friedman rank sum test to perform a difference analysis of the ECG abnormalities for each patient who exhibited the occurrence of PEs in different positions. A relevance analysis was carried out to clarify the relevance between the PEs at different positions and the number of ECG abnormalities. We performed regression analyses to determine the relationships between the severities of the PEs at different positions and both the corresponding ECG abnormalities and the degree of RVH. A 1-way analysis of variance was used to test whether the position of the PE affected blood pressure, pulmonary artery pressure, or the RVEDD. In addition, a 1-way analysis of variance was also used to analyze whether the RVEDD, BNP, or cTnT influences disease development. A Fisher discriminant analysis was used to analyze whether ECGs can predict the prognosis of patients with PE.

3. Results

3.1. Clinical presentation

A total of 147 patients with an average age of 56.36 ± 15 years were enrolled in this study, including 86 women and 61 men. Six patients exhibited hemodynamic instability (systolic blood pressure < 90 mm Hg), 1 patient exhibited a simple embolization within the pulmonary trunk, 89 patients demonstrated embolization of either the lobar arteries or the remote branches, and 57 patients demonstrated embolization of either the pulmonary trunk or the left or right MPAs and embolization of either the lobar arteries or the remote branches. The rate of dyspnea was 42.18%, whereas the rates of cough, chest pain, and hemoptysis were 26.53%, 14.97%, and 8.16%, respectively (Table 1).

Table 1
The clinical characteristics of the patients with PE

Character	Number (%) or mean ± standard deviation
Age (y)	56.36 ± 15
Male	61 (41.50%)
Systolic pressure < 90 mm Hg	6 (4.08)
Position of PE	
Pulmonary trunk/MPA	1 (0.68)
Lobar arteries or remote branches	89 (60.54)
Pulmonary trunk/MPA and either the lobar arteries or the remote branches.	57 (38.78)
Symptoms	
Dyspnea	62 (42.18)
Cough	39 (26.53)
Chest pain	22 (14.97)
Unilateral edema of a lower extremity	20 (13.61%)
Hemoptysis	12(8.16%)
Syncope	6 (4.08%)
Decreased level of consciousness or coma	5 (3.40%)

3.2. Table 2 depicts the ECG abnormalities of all enrolled patients

3.2.1. Depolarization abnormalities

Significant differences were observed in the incidence of SIQIIITIII (32.76% vs 10.11%, $P = .0004$) and RBBB (18.97% vs 1.12%, $P = .0002$) between the patients with pulmonary trunk/MPA embolisms and patients with lobar artery or remote branch embolisms.

3.2.2. Repolarization abnormalities

The most commonly observed ECG abnormalities among the patients with PE were nonspecific ST-T changes. The rate of NTWs in leads V1-V3/V6 in the pulmonary trunk/MPA embolism group was as high as 70.69%, which was significantly higher than the 21.35% noted in the lobar artery or remote branch embolism group ($P < .0001$).

Significant differences were also observed in the rates of STD in leads III and aVF (44.83% vs 15.73%, $P = .0001$), the STE in lead aVR (32.76% vs 7.87%, $P = .0002$), the NTWs in leads III and aVF (31.03% vs 10.11%, $P = .0008$), the STD in leadsV1-V3/V6 (20.69% vs 7.87%, $P = .0177$), and the STE in leadsV1-V3 and STD in V4-V6 (15.52% vs 6.74%, $P = .0022$) between the 2 groups. In addition, the number of NTWs in the pulmonary trunk/MPA embolism group was higher than that in the lobar artery or the remote branch embolism group (2.91 ± 2.69 vs 0.79 ± 1.9, $P < .0001$) (Table 2).

The incidence of QTc interval prolongation among patients with pulmonary trunk/MPA embolisms was higher than that among patients with either a lobar artery or remote branch embolism (15.52% vs 6.74%, $P = .0703$); however, this difference was not significant.

3.2.3. Arrhythmia

The incidence of sinus tachycardia was the second most common finding noted among the patients with PE, occurring in 29.93% of patients. The morbidity of the pulmonary trunk/MPA embolism group was higher than that of the lobar artery or remote branch embolism group (46.55% vs 19.01%, $P = .0002$) with respect to sinus tachycardia. However, no significant differences were observed with regard to the incidence of atrial arrhythmia between the 2 groups (10.34% vs 8.99%, $P = .7196$).

3.2.4. Additional ECG abnormalities

Twenty-six patients were diagnosed with RVH. The majority of these patients were in the pulmonary trunk/MPA embolism group, and this difference was significant (32.76% vs 7.87%, $P = .0002$). In addition,