European Review for Medical and Pharmacological Sciences 2016; 20: 1566-1570

A novel parameter for the diagnosis of acute pulmonary embolism: the T-wave peak-to-end interval

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Abstract. – OBJECTIVE: Acute pulmonary embolism (APE) is a very common disease that must be diagnosed and treated quickly and accurately to reduce significant morbidity and mortality rates. Acute pulmonary embolism is associated with numerous electrocardiographic (ECG) changes including prolonged QT interval with global T-wave inversion. The aim of the study was to investigate the relationship between the T-wave peak-to-end interval and diagnosis of APE, which has never been investigated in the literature.

PATIENTS AND METHODS: Seventy-three patients who were suspected of having APE took part in the present study. The Local Ethics Committee of Istanbul University, Turkey, approved the study protocol. Forty-one of the patients were diagnosed as having APE using computed tomography. Surface ECGs were taken in the initial assessment at admission. The Tp-Te interval was identified as the interval from the peak of the T-wave to the end of the T-wave. The measurements of the Tp-Te interval were taken using precordial leads. All measurements were compared using appropriate statistical tests. Statistical analysis was performed using SPSS version 22.0.

RESULTS: We enrolled 73 patients to the study, 41 of which were diagnosed as having APE. Men comprised 54% of the APE group. The mean ages in the APE (+) and APE (-) groups were 59.5 ± 14.5 years and 61±9.2 years, respectively. There was a significant increase in Tp-Te results in V1 ($p<0.01$). The Tp-Te interval was 74.21 ± 20.81 in the APE (+) group, whereas it was 59.73 ± 12.82 in APE (-) group ($p<0.01$).

CONCLUSIONS: Acute pulmonary embolism (APE) is a mortal condition and as such, rapid and accurate diagnosis is very important. Surface ECG can be used to measure Tp-Te in patients admitted to the emergency room with suspected APE in the differential diagnosis as a fast and easily accessible tool.

Key Words:
T-wave peak to end interval, Acute pulmonary embolism, ECG, T-wave, QT duration.

Introduction

Acute pulmonary embolism (APE) is a common disease that must be diagnosed and treated quickly and accurately to reduce significant morbidity and mortality rates, which can reach 17.4%[1,2]. The presenting symptoms and signs are nonspecific, so diagnostic tests are very important to establish the presence or absence of APE. This allows patients to avoid the risks of unnecessary anticoagulation or fatal thromboembolic recurrence[3,4].

Various coronary and non-coronary events are known to be associated with marked QT prolongation and global T-wave inversion[5-14]. Acute pulmonary embolism is associated with numerous electrocardiographic (ECG) changes including prolonged QT interval with global T-wave inversion[15,16]. The T-wave peak-to-end (Tp-e) interval is a relatively new marker for ventricular arrhythmogenesis and repolarization heterogeneity[17-20]. Prolongation of this has been associated with increased risk of mortality and cardiovascular events.

The aim of the study was to investigate the relationship between the T-wave peak-to-end interval and diagnosis of APE, which has never been investigated in the literature.

Patients and Methods

Study Population

We enrolled 73 patients who were admitted to emergency room with acute chest pain and/or dyspnea and underwent pulmonary computerized tomography (CT) angiography because of the suspicion of acute pulmonary embolism. The indications of pulmonary CT angiography were as follows: high clinical probability indicated by

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≥ 7 Wells score, or low/intermediate clinical probability indicated by < 7 Wells score, and positive D-dimer levels.

Exclusion criteria of the present study were as follows: pregnancy; sepsis; lung neoplasms; hemodialysis; acute coronary syndromes; acute cerebrovascular disease; aortic dissections; decompensated heart failure; surgery within the past 30 days; prior pulmonary embolism or deep venous thrombosis; severe chronic obstructive lung disease (FEV_1 < 50%); pulmonary hypertension; acute or chronic infectious diseases; acute or chronic inflammatory diseases such as rheumatoid arthritis; systemic lupus erythematosus; and vasculitis.

The patients diagnosed as having APE were defined as the APE (+) group (n=41) and the remaining individuals with normal pulmonary angiography were defined as the APE (-) group (n=32).

The demographic, clinical, and laboratory characteristics of the groups were taken from the patients' histories and results of physical examinations, which were collected by physicians in the emergency room at admission.

Electrocardiographic Measurements

A 12-lead electrocardiogram (ECG) was recorded on paper at 25 mm/s and 10 mm/Mv gain at rest in the supine position. All ECGs were scanned and analyzed. All QT interval measurements were undertaken manually and by two investigators who were medically qualified. The QRS interval was measured from the beginning of the Q wave, or in the absence of the Q wave, from the beginning of the R wave to the end of S (to its return to the isoelectric line)[21]. The time from the onset of the QRS complex to the end of the T-wave at which the isoelectric line crossed a tangential line drawn at the maximal down slope of a positive T-wave was identified as the QT interval. The QT interval was corrected for heart rate using Bazett's formula: $cQT=QT/\sqrt{R-R}$ (R–R interval)[22]. The Tp-Te interval was identified as the interval from the peak of the T-wave to the end of the T-wave. The measurements of the Tp-Te interval were taken using precordial leads[23]. Leads were excluded if the T-wave could not be clearly determined. An average value of three readings was calculated for each lead. Only recordings that had more than eight analyzable leads were included in the final analysis.

Ethical Approval

The Local Ethics Committee of Istanbul University, Turkey, approved the study protocol. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Statistical Analysis

For descriptive statistics of data; mean, standard deviation, median, minimum, maximum, frequency, and ratio values were used. Variables were analyzed for the presence of normal distribution using the Kolmogorov-Smirnov test. Quantitative variables were compared using Mann-Whitney U test and Independent sample *t*-test was used. Chi-square test was used for the analysis of qualitative data, and Fischer's test was used when Chi-square test conditions were not formed. Statistical analysis were performed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). $p < 0.05$ was considered statistically significant.

Results

We enrolled 73 patients to the study, 41 of whom were diagnosed as having APE. Men comprised 54% of the APE group and 45% of the non-APE group. The mean age in the APE (+) and APE (-) groups were 59.5 ± 14.5 years and 61±9.2 years, respectively. There was no significant difference between the groups for age or sex ($p = 0.61$, $p = 0.71$, respectively). There were significant heart rate and QRS duration differences between the APE (+) and APE (-) groups, as shown in Table I. The heart duration in the APE (+) group was 85.1 ± 17.94 and was 76.19 ± 10.21 in the APE (-) group. The QRS duration was 97.67 ± 22.34 in the APE (+) group and was 87.72 ± 11.42 in the APE (-) group (Table I). There was no significant difference in hypertensive and diabetic patient populations between the APE (+) and APE (-) groups (Table I).

When the QT duration was compared between groups, there was only a significant difference in lead V1, which was prominently prolonged (362.5 ± 44.8 vs. 339.42 ± 28.70, p=0.02). There was no significant difference in other precordial leads (Table I).

There was a significant increase in Tp-Te results in V1 ($p<0.01$) (Table II). In the APE (+) group, the Tp-Te interval was 74.21 ± 20.8, whereas it was 59.73 ± 12.82 in the APE (-) group ($p<0.01$).

Table I. Basal clinical, laboratory and electrocardiographic parameters in study population.

	APE(+)	APE(-)	*p*-value
Age	59.5±14.5	61± 9.2	0.61
Gender (Male) (%)	54 %	45 %	0.71
QRS duration	97.67±22.34	87.72± 11.42	0.02
Hypertension (n)	7	3	-
Diabetes mellitus (n)	4	1	-
Heart rate (bpm)	85.12 ± 17.94	76.19 ± 10.21	0.01
QTV1 (ms)	362.5 ± 44.08	339.42 ±28.70	0.02
QTV2 (ms)	371.4 ± 42.39	357.13 ± 26.30	0.11
QTV3 (ms)	371.42 ± 40.87	361.33 ± 23.16	0.24
QTV4 (ms)	366.48 ± 38.13	358.5 ± 24.06	0.31
QTV5 (ms)	365.31 ± 35.60	363.4 ± 25.95	0.81
QTV6 (ms)	368.5 ± 32.19	356.53 ± 24.87	0.10

Bolded data are statistically significant.

Discussion

The present study showed that the T-wave peak-to-end interval V1 derivation was prolonged in patients with acute pulmonary embolism (APE) when compared with patients who were suspected of having APE but were not diagnosed as such. Increased cardiovascular morbidity and mortality have been demonstrated in patients with APE in previous studies[1]. Many ECG patterns in acute pulmonary embolism have been extensively studied[23]. The T-wave changes in pulmonary embolism were first published in 1938. Subsequent studies[24-27] specified the association of T-wave inversion in right precordial leads with pulmonary embolism. However, global T-wave inversion with QT interval prolongation associated with acute pulmonary embolism has been described in one study[16]. The mechanism of this finding is not obvious but there could be two mechanisms: the first is coronary insufficiency, the second is catecholamine-mediated. Coronary insufficiency occurs in patients with acute pulmonary embolism; right ventricular infarction has been described during massive pulmonary embolism with angiographically normal epicardial coronary arteries[28-30]. Coronary insufficiency is the mechanism for these reported ECG changes in acute pulmonary embolism is still unclear. The second explanation for these ECG changes in acute pulmonary embolism could be via a catecholamine-mediated phenomenon, which can occur in patients with central nervous system disorders and pheochromocytoma[17]. Our finding of prolongation of the T-wave peak-to-end interval could also be explained by two possible mechanisms. The T-wave peak-to-end interval is a novel parameter that can easily be detected when a patient is admitted to the emergency room with suspected APE. The QT prolongation in right precordial leads is another parameter that can be seen in acute pulmonary embolism, but the T-wave peak-to-end interval is a more specific ventricular repolarization abnormality than QT interval prolongation.

Table II. T-wave peak to end interval in APE (+) and APE (-) groups.

	APE(+)	APE(-)	*p*-value
TpTeV1 (ms)	74.21 ± 20.81	59.73 ± 12.82	< 0.01
TpTeV2 (ms)	89.31 ± 18.97	81.81 ± 13.97	0.08
TpTeV3 (ms)	84.84 ± 26.91	79.10 ± 13.95	0.30
TpTeV4 (ms)	79.06 ± 22.97	73.72 ± 12.98	0.25
TpTeV5 (ms)	79.63 ± 16.75	78.87 ± 10.92	0.83
TpTeV6 (ms)	76.83 ± 19.15	69.84 ± 12.74	0.09

TpTe donates T-wave peak to end interval; V1, V2, V3, V4, V5, V6 are the precordial leads in electrocardiography.

One of the limitations of our study is that the number of patients was relatively small; however, it was hard to find patients with pulmonary embolism that also fulfilled the inclusion criteria of our study, to find patients not affected by conditions that could prolong the T-wave peak-to-end interval in other situations. Secondly, the prognosis of APE remains unclear in our study; the follow-up of patients will be a new topic for our next study. Finally, healthy subjects could be included as the third group of patients to compare the T-wave peak-to-end interval such that we could make an assessment of the pathologic prolongation of this parameter rather than in patients admitted to the emergency room who are not diagnosed as having APE.

Conclusions

Acute pulmonary embolism (APE) is a mortal condition. For this reason, rapid and accurate diagnosis is very important. Surface ECG can be used as a fast and easily accessible tool to measure Tp-Te in the differential diagnosis of patients admitted to the emergency room suspected of having APE.

Acknowledgements:
We have special thanks to David Chapman for English editing.

Conflicts of interest:
The authors declare no conflicts of interest.

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