Prognostic Significance of Inverted T Waves in Patients With Acute Pulmonary Embolism

Masami Kosuge, MD; Kazuo Kimura, MD; Toshiyuki Ishikawa, MD; Toshiaki Ebina, MD; Kiyoshi Hibi, MD; Kengo Tsukahara, MD; Masahiko Kanna, MD; Noriaki Iwashashi, MD; Jyun Okuda, MD; Naoki Nozawa, MD; Hiroyuki Ozaki, MD; Hideto Yano, MD; Tatuya Nakati, MD; Ikuyoshi Kusama, MD; Satoshi Umemura, MD

Background  The significance of inverted T waves remains unclear in patients with acute pulmonary embolism (PE).

Methods and Results  The relationship of the number of leads with inverted T waves to the severity of PE in 40 patients with acute PE was studied. Patients were classified into 3 groups according to the number of leads with inverted T waves on the admission electrocardiogram (ECG): 15 patients, ≤3 leads (group L); 12 patients, 4–6 leads (group M); and 13 patients, ≥7 leads (group H). In groups L, M and H, the rates of right ventricular dysfunction on echocardiography were 47%, 92% and 100% (p<0.01), respectively, and the rates of in-hospital complicated events (including death or the need for catecholamine support, cardiopulmonary resuscitation or mechanical cardiovascular support because of hemodynamic instability) were 0%, 8% and 46% (p=0.004), respectively. On multivariate analysis, arterial hypotension at presentation (odds ratio (OR) 8.96, p=0.049) and inverted T waves in ≥7 leads on the admission ECG (OR 16.8, p=0.037) were the only independent predictors of in-hospital complicated events.

Conclusions  The number of leads with inverted T waves may be a useful and simple marker of increased risk for early complications in patients with acute PE.  (Circ J 2006; 70: 750–755)

Key Words: Electrocardiography; Prognosis; Pulmonary embolism

G iven the wide range of in-hospital outcomes in patients with acute pulmonary embolism (PE), early risk stratification is essential for appropriate management. Previous studies have suggested that echocardiography1–2 computed tomography (CT)3, cardiac troponins4–6 or natriuretic peptides can improve risk stratification in patients with acute PE.7,8 However, because of its simplicity, widespread availability and low cost, the 12-lead electrocardiogram (ECG) has definite clinical advantages for the emergency triage of patients with acute PE, despite the availability of modern diagnostic strategies. Various ECG findings specific for acute PE have been reported; however, the relationship between ECG findings and the severity of acute PE remains unclear.9–18 Inverted T waves are frequently observed in lead III and precordial leads in patients with acute PE.9,11,14,15,17 Some9,15,16 but not all, studies have shown that inverted T waves are related to the severity of acute PE.17,18 Previous studies assessing the clinical significance of inverted T waves in patients with acute PE have focused mainly on the presence or absence of these findings; however, the relationship between the extent of inverted T waves and the severity of acute PE remains unclear. To clarify the clinical significance of inverted T waves, we studied the relationship of the number of leads with inverted T waves to disease severity at presentation and in-hospital outcomes in patients with acute PE.

Methods

Subjects  Among patients with acute PE who were admitted to our unit between January 2000 and November 2004, 40 (mean age 63±13 years, range 27–80; 15 men, 25 women) who fulfilled the following criteria were studied: (1) clinical signs and symptoms suggesting acute PE, such as acute onset of dyspnea, tachypnea, chest pain, palpitations, syncope, hypotension or shock; (2) no obvious past history of cardiopulmonary disease; and (3) fully assessable ECG on admission.19,20 The diagnosis of acute PE was confirmed by pulmonary angiography, lung perfusion scintigraphy or spiral computed tomographic scanning. PE was confirmed using pulmonary arterial angiography in 30 patients (75%), lung perfusion scintigraphy in 31 patients (78%) and CT scan in 26 patients (65%). Thirteen patients were positive for PE on all 3 examinations, and 21 were positive on 2 examinations. Patients were excluded from study if they were receiving drugs with potential effects on the ECG or if they had electrolyte abnormalities or metabolic disease. All patients gave informed consent. The study protocol was approved by our Internal Review Boards.

Electrocardiographic Evaluation  A 12-lead ECG was recorded on admission at a paper speed of 25 mm/s and an amplification of 10 mm/mV. All ECGs were examined by a single cardiologist who was blinded to all other clinical data. An inverted T wave was
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considered present if the depth was 0.5 mm in any lead except lead aVR or lead aVL.9 We analyzed the following ECG findings previously shown to be associated with PE: (1) arrhythmias; (2) pulmonary P: P waves ≥2.5 mm in limb leads or ≥1.5 mm in lead V1; (3) right axis deviation: QRS electrical axis >90°; (4) left axis deviation: QRS electrical axis ≤–30°; (5) complete right bundle block: QRS intervals ≥0.12 s; (6) incomplete right bundle block: QRS intervals = 0.10–0.11 s; (7) S1S2S3: the presence of S waves of at least 1.5 mm amplitude in leads I, II and III; (8) S1Q3T3: the presence of S waves in lead I and Q waves in lead III, each having amplitudes of ≥1.5 mm, in association with negative
T waves in lead III: (9) low voltage: greatest overall deflection of the QRS complex ≤5 mm in all limb leads; (10) right ventricular hypertrophy: the presence of R waves >5 mm or an R/S ratio of ≥1 in lead V1; (11) clockwise rotation: a shift in the transition zone (R= S) in the precordial leads to V5 or beyond; (12) ST elevation: elevation of ST segments ≥1.0 mm in any lead except lead aVR; and (13) ST depression: depression of ST segments ≥0.5 mm in any lead in the absence of complete bundle branch block or ventricular hypertrophy.9–18

Echocardiographic Evaluation

Right ventricular function was assessed using transthoracic echocardiography. Right ventricular dysfunction was diagnosed if patients had any of the following findings: (1) abnormal motion of the interventricular septum; (2) dilatation of the right ventricle (diastolic diameter ≥30 mm); (3) hypokinesis of the right ventricle; or (4) tricuspid valve regurgitation (jet velocity >2.5 m/s).19

Definition of Clinical Endpoint

Statistical analysis focused on the in-hospital period. The clinical endpoint of the present study was overall mortality and a complicated course, defined as death or 1 of the following: need for catecholamine support of blood pressure; cardiopulmonary resuscitation; or mechanical cardiovascular support (intra-aortic balloon pumping and percutaneous cardiopulmonary support) due to hemodynamic instability.6

Statistical Analysis

Continuous data are expressed as means±SD, and categorical data are expressed as percentages. Analysis of variance was used for continuous variables. Chi-square analysis was used to compare categorical variables. A cut-off value of leads with inverted T waves was set on the basis of receiver operating characteristics curve analysis to identify patients with complicated events. Multiple logistic regression analysis was used to identify clinical predictors of clinical endpoints among the variables associated (p=0.2) with endpoints on univariate analysis. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. Differences were considered statistically significant at p<0.05. Data were analyzed with the use of SPSS software (Release 10, SPSS Inc, Chicago, IL, USA).

Results

Study Group

Baseline characteristics and ECG findings of the study group are presented in Tables 1 and 2. Inverted T waves were commonly observed in leads III and V1–3, but were less common in leads II and V5–6. Inverted T waves were not observed in lead I in any patient. Patients were classified into 3 groups according to the number of leads with inverted T waves on the admission ECG: group L, 15 patients with inverted T waves in ≤3 leads; group M, 12 with inverted T waves in 4–6 leads; and group H, 13 with inverted T waves in ≥7 leads (Fig 1). There were no significant differences between the 3 groups with regard to age, sex, history of cancer, syncope, deep vein thrombosis, time from symptom onset to admission, time from symptom onset to ECG or heart rate at presentation. There was a slightly but not significantly higher incidence of arterial hypotension at presentation (defined as a systolic blood pressure persistently <90 mmHg) in group H. Patients in group H had the highest frequencies of cardiovascular collapse requiring resuscitation, catecholamine administration and mechanical cardiopulmonary support.
These treatments were not required by any patient in group L. Right ventricular dysfunction on echocardiography was more frequent in groups M and H than in group L.

Among 30 patients (75%) in whom pulmonary arterial angiography was performed in the acute phase, massive PE (defined as obstruction or filling defects of either both main pulmonary arteries or 2 or more lobar pulmonary arteries, including those in the lingula, or an equivalent amount of emboli in other vessels) was most frequently observed in group H. Pulmonary artery pressure was measured in 32 patients (80%) during the acute phase and in 26 (65%) during the chronic phase. Among these patients, those in group H had a higher mean pulmonary artery pressure during the acute phase, but there was no difference among the 3 groups in mean pulmonary artery pressure during the chronic phase.

There were no differences between the 3 groups with regard to arrhythmias, pulmonary P, right axis deviation, right bundle branch block, S1S2S3, low voltage, right ventricular hypertrophy, ST elevation or ST depression. The maximum depths of inverted T waves were greater in groups M and H than in group L. There was a slightly but not significantly higher incidence of S1Q3T3 in group H. Left axis deviation was observed in only group H. Patients in group H had the highest incidence of clockwise rotation.

Multivariate Predictors of Clinical Endpoint

During hospitalization, 6 patients (15%) were rescued from fatal cardiopulmonary crises using mechanical cardiopulmonary support (intra-aortic balloon pumping and percutaneous cardiopulmonary support), and 1 patient (2.5%) died. A total of 7 patients (18%) had clinical endpoints, as defined in the Methods. Univariate analysis revealed an association of clinical endpoint with arterial hypotension (p<0.001), right ventricular dysfunction (p=0.12), complete right bundle block (p=0.020) and the number of leads with inverted T waves (p<0.001). However, the clinical endpoint was unrelated to other clinical and ECG findings, including the maximum depth of negative T waves. Fig. 2 shows the sensitivities and specificities for predicting in-hospital complications according to the number of leads with inverted T waves on the admission ECG. The cut-off value providing the best sensitivity and specificity was 7 leads with inverted T waves. In the multivariate models, arterial hypotension (OR 16.8, 95% CI 1.17–212.8, p=0.037) and natriuretic peptides are useful for risk stratification in patients with acute PE.

Discussion

The present study showed that inverted T waves were frequently observed in leads III and V1–3 in patients with a clinical diagnosis of acute PE, but were also noted in leads II, aVR or V4–6 in some patients. The number of leads with inverted T waves was closely associated with the severity of acute PE as evaluated using echocardiography or pulmonary angiography, as well as with an in-hospital complicated course, including death or the need for catecholamine support, cardiopulmonary resuscitation or mechanical cardiovascular support due to hemodynamic instability. The number of leads with inverted T waves was also the strongest predictor of these complications. Inverted T waves are thus useful for emergency triage of patients with acute PE.

Early identification of high-risk patients with acute pulmonary PE is a major clinical issue with important therapeutic implications. Acute right ventricular dysfunction, associated with clinical and hemodynamic instability at presentation, is also a major determinant of the in-hospital outcome of PE. Also, echocardiography can identify high-risk patients with right ventricular failure by detecting right ventricular enlargement and hypokinesis. However, the evaluation of echocardiographic findings depends to some extent on the experience of the attending physician, and the reproducibility of this procedure is controversial. Furthermore, the quality of echocardiographic findings is sometimes poor in overweight or mechanically ventilated patients. Recent studies have shown that cardiac troponins and natriuretic peptides are useful for risk stratification in patients with acute PE. A more recent investigation suggests that right ventricular enlargement assessed on the basis of reconstructed 4-chamber views of the heart on chest CT (newer generation, multidetector-row scanners) indicates a risk of life-threatening PE. However, the 12-lead ECG remains the most widely performed initial diagnostic test. The 12-lead ECG is simple, prompt, ubiquitously available, generally comprehensive and inexpensive. If the 12-lead ECG could identify patients with high-risk acute PE, triage would be faster and easier. Acute PE is associated with a number of ECG abnormalities, but has extremely diverse manifestations and is liable to be affected by factors such as the degree of hemodynamic instability and the timing of ECG recording. Of the many ECG abnormalities associated with acute PE, inverted T waves are the most common as well as the most persistent change. Inverted T waves occur in 17–68% of patients with acute PE. The frequency of inverted T waves in the present study was higher than those in previous studies, probably because of differences in the definition of inverted T waves. In the present study, we considered inverted T waves with a depth of only 0.5 mm to be clinically significant, although this criterion is not universally accepted. It has been reported that patients in whom T waves were inverted 0.5 to 1.0 mm had hemodynamic, arteriographic...
and perfusion abnormalities comparable to those in patients in whom T waves were inverted more than 3.0 mm. Several studies have suggested that inverted T waves are related to the severity of acute PE, whereas others have not. Our findings suggest that the number of leads with inverted T waves is related to the severity of acute PE, and that the number of leads with negative T waves increased after admission, whereas the number of leads with negative T waves remained unchanged. These findings suggest that ECG evaluation on admission can play an important role in early risk stratification; nevertheless, ECG changes after admission should also be closely monitored. Further prospective studies in larger numbers of patients are required to confirm the prognostic usefulness of inverted T waves in patients with acute PE.

Conclusions

Our findings suggest that the number of leads with inverted T waves on admission ECG may be a useful and simple marker of increased risk for early complications in patients with acute PE. The use of this marker may help to identify patients most likely to benefit from more aggressive therapy.

References


