The Differential Diagnosis of Acute Pericarditis from the Normal Variant: New Electrocardiographic Criteria

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SUMMARY We examined the quantitative electrocardiographic differentiation of acute pericarditis from normal variant ST/T changes. The ECGs of 19 patients with acute pericarditis were compared with those of 20 subjects with typical normal variant changes. Patients were excluded if their ECGs demonstrated conditions that markedly altered repolarization. The positive predictive values (PPV) and negative predictive values (NPV) of previously reported criteria were not high (PPV = 0.54–0.83, NPV = 0.56–0.58). In contrast, in the present study, a T-wave amplitude in lead V₆ of ≤ 0.3 mV diagnosed acute pericarditis (p < 0.005, PPV = 0.85, NPV = 0.85), but there was overlap of patients between the groups. The ratio of the amplitude of the onset of the ST segment to the amplitude of the T wave in that lead (ST/T ratio in V₆) proved to be the most reliable discriminator. An ST/T ratio ≥ 0.25 diagnosed all patients with acute pericarditis (p ≤ 0.005, PPV = 1.0, NPV = 1.0). The ST/T ratio ≥ 0.25 in V₁, V₆ (both p < 0.005, PPV = 0.87, NPV = 1.0) and I (p ≤ 0.005, PPV = 0.80, NPV = 0.81) were also significant discriminators. Thus, if V₁ is unavailable, an ST/T ratio ≥ 0.25 in V₁, V₆, or I is highly suggestive of acute pericarditis. An ST/T ratio ≥ 0.25 in V₆ discriminated the ECGs of all patients with acute pericarditis from normal variants in this study.

THE PROBLEM of differentiating the ECG of acute pericarditis from the normal variant with early repolarization has long concerned the clinician and the electrocardiographer. Acute pericarditis is a common cause of chest pain and abnormal ECGs (fig. 1), especially in young adults. The ST-T changes present in the normal variant ECG (fig. 2) have been reported in 2% of healthy young adults and may present a diagnostic dilemma if the person presents with chest pain or an acute febrile illness. Distinguishing the two conditions on the basis of a single ECG is difficult.

The ECG changes of acute pericarditis consist of ST-segment elevation with an ST vector that is directed toward the area of pericarditis, and are thought to represent an injury current in response to an inflammatory epimyocarditis, and usually undergo a typical evolution over days to weeks. On the other hand, although similar in appearance, the repolarization changes seen in the normal variant ECG are thought to be due to autonomic nervous system imbalance in the myocardium resulting in varying rates of repolarization and tend to be stable over a period of years. Investigations attempting to distinguish these two conditions have yielded conflicting results, and the differential criteria have been complex. Other investigators have concluded that it is not possible to differentiate between acute pericarditis and normal ST-T variations on the basis of a single ECG, and that serial ECGs in conjunction with the clinical setting are required. Furthermore, with the increased use of computerized ECG interpretive systems, the need for validated criteria as a data base has been emphasized.

The purpose of this study was to determine the diagnostic accuracy of present criteria for differentiating normal variant repolarization changes from acute pericarditis and to test the accuracy of new criteria established in our laboratory.

Materials and Methods

Patient Selection

Because the purpose of the study was to differentiate acute normal variant ECGs from acute pericarditis, patients were excluded if their ECGs revealed conditions that markedly altered repolarization, such as left bundle branch block, severe right or left ventricular hypertrophy or acute myocardial infarction. Over 3 years, 77 patients had a discharge diagnosis of acute pericarditis, and 58 of their records were available for review. Nineteen patients were considered to have acute pericarditis. Twenty-four patients did not fulfill the criteria and were considered misdiagnosed. Eight patients did not have serial ECGs available for analysis; because serial electrocardiographic changes consistent with the evolution of acute pericarditis were required for the diagnosis to be confirmed, these patients were excluded. Nine patients had significant electrocardiographic abnormalities: two acute anterolateral myocardial infarction, six severe left ventricular hypertrophy and one patient severe right ventricular hypertrophy.

Group 1 consisted of 19 consecutive patients with unequivocal acute pericarditis. All had serial ECG changes consistent with the evolution of acute pericarditis and a pericardial friction rub documented by at least two observers. Of the 19 patients, 15 had chest pain, 16 were febrile and 12 had leukocytosis (WBC > 11,000). M-mode echocardiograms were recorded in 17 patients and in 13 revealed a pericardial effusion. The ECG chosen for analysis was the one that corresponded to Spodick's stage I.
Group 2, which included patients with the normal variant, was composed of 20 healthy adults without clinical or historical evidence of cardiovascular disease whose 12-lead ECGs demonstrated typical normal variant repolarization changes.\textsuperscript{5, 6, 7}

Measurements

To determine PR-segment abnormalities, the TP segment was used as the baseline (fig. 3). For all other measurements, the end of the PR segment was used as the baseline. The mean frontal and horizontal plane vectors were calculated for the P wave, PR segment, QRS, ST segment and T wave. The amplitude of the onset of the ST segment and T wave were measured in leads I, II, V\textsubscript{2}, V\textsubscript{5}, V\textsubscript{6} and I. Differences between ST and T vectors (in degrees) were calculated by subtracting the mean T vector from the mean ST vector. Thus, a positive angle meant that the mean ST vector was to the right of the T vector, and a negative angle meant that the mean ST vector was to the left of the mean T vector. Likewise, the QRS-ST angle was obtained by subtracting the QRS vector from the ST vector. The ST/T ratio was obtained by dividing the amplitude of the onset of the ST segment by the amplitude of the T wave in that lead. The ST/T ratio in lead V\textsubscript{6} was calculated in two ways: using both the TP segment and the end of the PR segment as the baseline for measuring ST-segment and T-wave amplitudes. A flat or negative T wave resulted in an ST/T ratio that could not be calculated for that lead.

Statistical Methods

The mean and standard errors of the mean were calculated for all groups of data. The statistical significance was calculated using the t test for non-paired variables.\textsuperscript{13} The sensitivity, specificity and positive and negative predictive values were calculated by standard methods.\textsuperscript{14} The positive predictive value is an expression of how often a test is correct when its result is positive; the negative predictive value expresses how often a test is correct when its result is negative. The predictive value is 0 if the test is never correct and is 1.0 if the test is always correct.

Results

Patient Population

Group 1 consisted of 13 males and six females, 10 whites and nine blacks. The mean age was 40 years (range 16–69 years). The etiology of the pericarditis was idiopathic (presumed to be of viral origin) in seven, chest trauma in five, postpericardiotomy in

Figure 1. ECG of acute pericarditis. There is PR deviation in both frontal and horizontal planes and the frontal plane ST vector is horizontal and to the left of the QRS vector. The ST/T ratio in V\textsubscript{6}, V\textsubscript{5} and I are all greater than 0.25.

Figure 2. Normal variant repolarization ECG. The ST vector is directed to the left, anterior and inferior, and the lateral T wave amplitude is high (greater than 0.5 mV). The ST/T ratio in V\textsubscript{6} is less than 0.25.
two, associated with metastatic neoplasms in two (one lung carcinoma and one osteogenic sarcoma), autoimmune disease in two, and chronic renal failure in one. Echocardiograms were obtained in 17 patients and were interpretable in 16. A pericardial effusion was not demonstrable in three patients, was small in five, moderate in six, and large in two. One patient had hemodynamic evidence of cardiac tamponade.

Group 2, the normal variant population, was composed of 20 males, mean age of 26.4 years (range 24-30 years). There were 17 whites and three orientals.

Previous criteria for differentiating acute pericarditis and normal variant ECGs were reviewed^1, 4, 8, 9 and applied to the present study population (fig. 4).

PR Segments

In the pericarditis group, PR segments were displaced from the baseline in five of 19 patients in both the frontal plane and horizontal plane, in the frontal plane only in six and in the horizontal plane in none. In the normal variant group, one of 20 patients had displaced PR segments in both the frontal and horizontal planes and none had PR-segment displacement isolated to the frontal or horizontal plane. The positive predictive value for PR-segment deviations in both the frontal and horizontal planes indicating
pericarditis, was 0.83 and the negative predictive value was 0.58.

Frontal Plane Mean ST-segment Vector

The mean frontal plane ST vector for the pericarditis patients was closer to 0 than the normal variants ($p < 0.025$). The positive predictive value of a frontal plane ST vector $< 30^\circ$ diagnosing acute pericarditis was 0.78 and the negative predictive value was 0.57.

Horizontal Plane Mean ST-segment Vector

The pericarditis patients had a mean horizontal plane ST vector to the left of the normal variant group, but few were less than $30^\circ$. The positive predictive value of a horizontal plane ST vector $< 30^\circ$ was 0.60 and the negative predictive value was 0.56.

Frontal Plane ST-T Vector Angle

The angle between the mean frontal plane ST-segment vector and the mean frontal plane T-wave vector was expressed as positive if the ST-segment vector was to the right of the T-wave vector and negative if to the left. The frontal plane ST-T-vector angle in pericarditis was not significantly different from that in the normal variant group ($p > 0.10$).

Frontal Plane QRS-ST Vector Angle

The QRS-ST angle was expressed as positive if the ST-segment vector was to the left of the QRS vector. The frontal plane QRS-ST angle in pericarditis was slightly to the left of the QRS-ST angle in the normal variants ($p \leq 0.05$). The positive predictive value of an ST-segment vector to the left of the QRS vector in the frontal plane indicating pericarditis was 0.54 and the negative predictive value was 0.58.

T-wave Amplitude

The T-wave amplitude in acute pericarditis was significantly less than normal variants ($p < 0.05$ to 0.005) in leads I, II, V$_2$, V$_4$, V$_5$ and V$_6$ (fig. 5).

Ratio of ST-segment Amplitude to T-wave Amplitude (ST/T ratio)

The ST/T ratios in acute pericarditis were significantly greater than normal variants ($p \leq 0.005$) in leads I, II, V$_4$, V$_5$ and V$_6$. In lead I, the positive predictive value of an ST/T ratio $\geq 0.25$ indicating pericarditis was 0.88 and the negative predictive value was 0.95 (fig. 6). In lead II, the positive predictive value of an ST/T ratio $\geq 0.25$ was 0.75 and the negative predictive value was 0.81. The positive predictive value of an ST/T ratio in lead V$_4 \geq 0.25$ was 1.0 and the negative predictive value was 0.87. The positive predictive value for an ST/T ratio $\geq 0.25$ in lead V$_5$ was 0.88 and the negative predictive value was 0.95 (fig. 6). Although these values were all highly significant, an overlap occurred in all leads between pericarditis and normal variant groups, as indicated by the positive and negative predictive values.

ST/T Amplitude Ratio in Lead V$_5$

The ratio of ST-segment amplitude to T-wave amplitude in lead V$_5$ was $0.57 \pm 0.06$ in the pericarditis group and $0.13 \pm 0.01$ in the normal variant group ECGs ($p \leq 0.005$). No overlap occurred between the groups, in that the smallest ST/T ratio in pericarditis was 0.25 and the largest ST/T ratio in the normal variants was 0.20; therefore, the positive predictive value was 1.0 and the negative predictive value was also 1.0 (fig. 6). The ST/T ratio among the

**Figure 5.** T-wave amplitude. Although the T-wave amplitude is significantly higher in the normal variant group in I, V$_2$ and V$_6$, there is still overlap between the groups. The dashed lines represent breakpoints used in calculating tests of predictive accuracy.
patients with pericarditis when subdivided by sex was: males 0.56 ± 0.06, females 0.48 ± 0.11, and the ratio when subdivided by age was: younger than 40 years 0.50 ± 0.06, greater than 40 years 0.57 ± 0.09. In all the etiologic subsets of pericarditis, the ST/T ratio was 0.38 or greater. Thus, an ST/T ratio in lead V₆ of 0.25 or greater distinguished all patients with pericarditis from those with normal ST-segment elevation in our study population. If the TP segment was used as the baseline in lead V₆, 17 of 19 patients with acute pericarditis had an ST/T ratio ≥ 0.25 and all normal variant subjects had an ST/T ratio < 0.25. Thus, using the TP segment as the baseline, the positive predictive value of an ST/T ratio of ≥ 0.25 diagnosing acute pericarditis was 1.0 and the negative predictive value was 0.91.

Discussion

Numerous authors have described qualitative ECG changes in acute pericarditis⁴⁻⁶,¹⁰ and have commented on the difficulty of distinguishing these changes from acute myocardial infarction⁵,⁶ and early repolarization.⁵, ³, ⁷ However, only Spodick¹, ⁴, ¹⁰ provided criteria from which quantitative conclusions may be made differentiating acute pericarditis from normal variants. Although Spodick's criteria allowed the differentiation between the means of these two groups (p ≤ 0.025), the data significantly overlap (fig. 4). Consequently, these criteria have limited value in interpreting individual ECGs.

In evaluating the ability of a test to discriminate between the presence or absence of a condition, the use of a test of the statistical difference between the means of the two study populations may be misleading. A highly significant difference between means can occur between two populations with a marked overlap of data. Consequently, the evaluation of the usefulness of a test in making individual case decisions requires an estimate of its predictive accuracy. Although the specificity and sensitivity have been used for this purpose because they are expressions of how frequently the test will detect the presence or absence of a condition in the sample population, the positive predictive value and negative predictive value express the reliability of a test if its result is positive or negative.¹⁴, ¹⁷ Because the value of a test in clinical practice is often more related to its ability to aid in individual case decisions than to distinguish two populations, or in detecting a condition in a population, we believe that the knowledge of the positive and negative predictive values is useful in clinical situations.

After analyzing various potential electrocardiographic criteria for differentiating acute pericarditis from normal variants, in this study population we conclude that an ST/T ratio in lead V₆ ≥ 0.25 was the best discriminator between the ECGs of acute pericarditis and normal patients. A review of the 18 published ECGs of stage I acute pericarditis and normal variants¹, ³, ⁵, ⁶, ⁸⁻¹⁰, ¹⁵, ¹⁸ also shows a high, although not complete, predictive accuracy of this criterion. There was one false-negative and one false-positive diagnosis of acute pericarditis using the ST/T ratio ≥ 0.25 in V₆. Thus, when applied to illustrations in the literature, the positive predictive value is 0.90 and the negative predictive value is 0.88.

Although others have commented on the large amplitude of the T waves in normal variants,⁵, ¹⁰ no quantitative data have been presented. In the present study, the amplitude of the T wave in V₆ also proved to be a significant discriminator in that no patient with acute pericarditis had a T wave greater than 0.5 mV and no normal patient had a T wave less than 0.3 mV (fig. 5). However, a T-wave amplitude of 0.3–0.5 mV could be caused by either condition.
The ST/T ratio in leads I, V_4 and V_6 also discriminated between acute pericarditis and normal patients, although the positive and negative predictive values were slightly lower than those in V_6. If lead V_6 is not available because baseline artifact or chest bandages are present, an ST/T ratio ≥ 0.25 in any of leads I, V_4 or V_6 is highly suggestive of acute pericarditis.

The PR segment was chosen as the baseline for measuring repolarization changes for several reasons. First, atrial repolarization may alter the PR segment to a variable degree. This alteration occurs particularly in patients with sinus tachycardia or with high catecholamine states, as occurs in patients with respiratory distress. Thus, measurements from the TP interval will not exclude atrial repolarization changes, whereas measurements made from the PR segment will. Also, the TP segment may be very difficult to identify as a stable baseline. This problem is more pronounced in tachycardic patients in that the T wave may distort the P wave in the ECG. If the TP segment was taken as the baseline in the present series, 17 of 19 of the acute pericarditis patients (89%) still had an ST/T ratio in lead V_6 greater than 0.25. Although what the baseline for measurement of ST segments should be is controversial, the use of the PR segment in this criterion appears to be a better discriminator.

Spodick's criteria (PR-segment deviation in both the frontal and horizontal planes and a frontal plane ST segment vector that is horizontal and to the left of the QRS vector) did not reliably distinguish between acute pericarditis and normal variants in our study population. A number of explanations seem plausible. First, our sample population was small and may not have had the same range of underlying causes and associated diseases. However, Bruce and Spodick state that the presence of heart disease or underlying cause of the pericarditis are not associated with particular ECG abnormalities. Our study confirms this concept: Our patient population had no significant difference in the ST/T ratio in V_6 when subgrouped by age, sex or cause of the pericarditis. Second, since the QRS, ST-segment and T-wave vectors are partly dependent on heart position and body habitus, our patients could have had a more heterogeneous body type, thereby producing more variation in Spodick's criteria. Since the ST/T ratio in V_6 is an expression of the relative magnitude of two vectors in a single lead, this ratio will be less dependent on changes in heart position than will criteria that rely on the absolute direction of vectors. Finally, the time of obtaining the ECG in the disease stage may have been different. Although we used the same criteria for stage I pericarditis as did Spodick and Bruce and Spodick, some criteria may be more or less sensitive in the very early, rapidly evolving stages of acute pericarditis.

Acknowledgment

The authors thank Pamela Carbajal for her secretarial assistance in the preparation of this manuscript.

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The differential diagnosis of acute pericarditis from the normal variant: new electrocardiographic criteria.
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Circulation. 1982;65:1004-1009
doi: 10.1161/01.CIR.65.5.1004

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1982 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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