

Early Electrocardiographic Diagnosis of Acute Myocardial Infarction in the Presence of Ventricular Paced Rhythm

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As the general population ages, the number of patients who present to emergency departments with permanent pacemakers and symptoms suggestive of acute myocardial ischemia are expected to increase. The exact prevalence of coronary artery disease in pacemaker recipients is not known, but the fact that in a recent national survey, 75% of patients undergoing pacemaker implant were aged >60 years¹ would suggest that the risk of coronary events in this population is relatively high. Usually, therapeutic decisions in patients with acute chest pain are based on the 12-lead electrocardiogram (ECG) because ST-segment elevation is a highly specific sign for acute myocardial infarction (AMI),² but the presence of ventricular pacing limits the diagnostic value of the ECG. Inhibition of the pacemaker to expose the underlying rhythm is not always feasible. Furthermore, the phenomenon of "T-wave memory"³ may obscure electrocardiographic changes generated by myocardial injury. We examined the value of the initial 12-lead ECG for the diagnosis of AMI in the presence of ventricular pacing in patients enrolled in an international trial of 4 thrombolytic strategies.

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All patients enrolled in the Global Utilization of Streptokinase and t-PA for Occluded Coronary Arteries-I (GUSTO-I) trial⁴ who had permanent ventricular pacing (single- or dual-chamber) in the prerandomization ECG were studied. Of 41,021 patients, 32 (0.1%) had ventricular pacing, and all had enzymatically confirmed AMI. One ECG showing QRS complexes compatible with left ventricular pacing and 14 others showing intrinsic beats, fusion beats, or both, were excluded from the analysis. Thus, the admission ECGs from 17 patients (11 with dual-chamber pacing, 6 with single-chamber ventricular pacing) were compared with an equal number of ECGs from randomly selected external control subjects who had angiographically confirmed, stable coronary disease and permanent endocardial right ventricular pacing. The median age of study patients was 71.5 years. Classic electrocardiographic criteria for AMI (Table I)⁵⁻⁷ were blindly assessed by a single investigator (SLP) to prevent interobserver variability. The direction and magnitude of ST deviation measured at the J point and their relation to the QRS complex polarity were particularly scrutinized. Receiver-operator characteristic curves for ST-segment elevation identified the point of maximal overall accuracy at ST elevation ≥ 1 mm for leads with

concordant QRS polarity (i.e., with predominantly positive QRS complex) (area under curve 0.57, sensitivity 18%, specificity 94%), and at ST elevation ≥ 5 mm for leads with discordant QRS polarity (area under curve 0.66, sensitivity 53%, specificity 88%). ST elevation ≥ 5 mm in leads with negative QRS complexes was the only electrocardiographic criterion with both relatively high specificity and statistical significance for the diagnosis of AMI at admission (positive likelihood ratio 4.41, $p = 0.025$, relative risk 2.35, 95% confidence interval 1.26 to 4.39). Two other criteria also had acceptable specificity for the diagnosis of AMI: ST elevation ≥ 1 mm for leads with concordant QRS polarity (positive likelihood ratio 3.1, $p = \text{NS}$) and ST depression ≥ 1 mm in leads V_1 , V_2 , or V_3 (sensitivity 29%, specificity 82%, positive likelihood ratio 1.64, $p = \text{NS}$). No criteria involving the QRS complex or isolated T waves (criteria 3 to 9 in Table I) reached either statistical significance or a specificity $\geq 80\%$. Figure 1 shows the ECG of a patient with ventricular pacing and AMI.

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Making a positive diagnosis of AMI at the time of presentation can be difficult. In the past, early diagnostic certainty was not essential. The categorization of acute chest pain into "AMI," "unstable angina," or "non-cardiac chest pain" was gradually accomplished through the serial analysis of ECGs and cardiac enzymes. However, the availability of thrombolytic therapy has drastically reduced the time frame in which an accurate diagnosis of AMI must be made.⁸ In the presence of chronic ventricular pacing, superimposed ischemic changes can be recognized when the ECG is compared with a previous one. Unfortunately, timely availability of a previous ECG is unusual. Thus, the importance of a thorough evaluation of the initial ECG for adequate patient triage cannot be overemphasized. In the admission ECG of GUSTO-I patients with ventricular pacing, only criteria related to ST-segment deviation were associated with evolving myocardial infarction, whereas previously proposed criteria involving the QRS complex were not. These discrepancies could be explained by the fact that the GUSTO-I study included patients with acute infarction, whereas previous studies have not always differentiated between acute and previous infarction.⁷

Uncomplicated ventricular pacing is characterized by secondary repolarization changes of opposing polarity to that of the predominant QRS deflection. During pacing from the right ventricular apex, most electrocardiographic leads show a predominantly negative QRS complex followed by ST-segment elevation and positive T waves similar to those elicited by acute coronary occlusion. It is important to identify a threshold for ST-segment elevation that can correctly discriminate between

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TABLE 1 Electrocardiographic Criteria Analyzed in Patients With Ventricular Pacing

1. ST-segment elevation and its concordance with QRS polarity in all ECG leads
2. ST-segment depression in all ECG leads
3. Presence of Q waves in 2 contiguous precordial leads or in 2 limb leads. Q waves were considered present if they measured ≥ 20 ms in lead V_4 , ≥ 30 ms in leads I, II, aVL, V_5 , or V_6 , and regardless of width in V_1 to V_3 .
4. R-wave regression from V_1 to V_4
5. QS pattern from V_1 to V_4
6. Positive T waves in V_5 or V_6
7. Notching ≥ 0.05 second in the ascending limb of the S wave in leads V_3 or V_4 (sign of Cabrera)
8. Notching ≥ 0.05 second of the ascending limb of R waves in leads I, aVL, V_5 , or V_6 (sign of Chapman)
9. Terminal S wave in V_5 or V_6

ECG = electrocardiographic.



FIGURE 1. Electrocardiogram from a patient in the Global Utilization of Streptokinase and t-PA for Occluded Coronary Arteries-I trial with dual-chamber pacing and acute myocardial infarction, showing ST-segment elevation ≥ 5 mm in leads V_2 and V_3 (i.e., with discordant QRS polarity), and ≥ 1 mm ST-segment elevation in V_4 to V_6 (i.e., with concordant QRS polarity).

AMI and the expected repolarization pattern. We found that ST-segment elevation ≥ 5 mm was most indicative of AMI in leads that had predominantly negative QRS complexes. Conversely, ST-segment elevation concordant with the QRS polarity is not expected in uncomplicated ventricular pacing; we found that any degree of ST-segment elevation in a lead with a predominantly positive QRS complex was a highly specific sign of AMI. Likewise, because the QRS complex is predominantly negative during ventricular pacing in leads V_1 , V_2 , and V_3 , ST-segment depression should not be present in these leads. In our study, ST-segment depression in leads V_1 , V_2 , or V_3 had a specificity of 82% for acute infarction. This could represent either posterior "Q wave" infarctions,⁹ or "ST depression (subendocardial)" infarcts.¹⁰

Electrocardiographic patterns of acute myocardial injury or infarct during ventricular pacing may vary with the site of necrosis.⁷ Our population, although the largest available from recent AMI trials, is still relatively small. The resulting impossibility to subcategorize infarcts by location constitutes a limitation of our study. If the enrollment rates in GUSTO-I are representative of the clinicians' disposition to administer thrombolytic therapy, the small proportion of patients with ventricular pacing (0.1%) would reflect the state of diagnostic uncertainty that a paced rhythm provokes. This may be responsible for many delays or exclusions from treatment in clinical practice. A recent survey in treatment practices for AMI in the United States showed that patients with "non-diagnostic" ECGs are less likely to undergo thrombolysis.¹¹ The availability of highly specific criteria for the diagnosis of AMI could shift the triage process in patients with chest pain from a "rule-out" to a "rule-in" approach.¹²

Our study suggests that certain changes in the ST segment in patients with endocardial right ventricular pacing and chest pain are specific for the early diagnosis of AMI. Such signs may reduce or eliminate the need to inhibit the pacemaker or wait for serial electrocardiographic changes before offering appropriate treatment.

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