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A quantitative evaluation of ST-segment changes on the 18-lead electrocardiogram during acute coronary occlusions

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Abstract This study determined quantitative ST segment changes on the 18-lead electrocardiogram (ECG) during occlusions in each of the coronary arteries.

Methods: Continuous 18-lead ECGs, including standard 12 leads, posterior ($V_{7\text{-}9}$), and right ventricular (RV) leads ($V_{3\text{-}5R}$) were recorded for 155 subjects undergoing percutaneous coronary occlusions, the maximum intervention.

Results: During 58 left anterior descending (LAD) coronary occlusions, the maximum ST elevation and depression were in V_3 (4.2mm) and III (−0.9mm), respectively. During 44 right coronary artery (RCA) occlusions, the maximum ST elevation and depression were in III (2.2mm) and aVL (−1.4mm), respectively. During 53 left circumflex (LCX) occlusions, the maximum ST elevation and depression were in V_7 (0.8mm) and V_2 (−1.6mm), respectively.

Conclusions: ST elevation often occurred in the anteroapical (V_1-V_6), lateral (I, aVL), and RV lead V_{3R} during LAD occlusions; in the inferior, RV, and posterior leads during RCA occlusions; and in the posterior, inferior, and apical leads (V_5-V_6) during LCX occlusions.

Keywords: ST-segment changes; 18-Lead electrocardiogram; Acute coronary occlusions; Myocardial aschemia

Introduction

Controlled coronary artery occlusion during percutaneous coronary intervention (PCI) produces individual-specific reproducible "ischemic fingerprints" and is used as a clinical model to assess myocardial ischemic changes on the electrocardiogram (ECG). Bush et al[1] investigated the utility of the standard 12-lead ECG during PCI to determine the most sensitive ECG leads for identifying acute myocardial ischemia in individual patients. Limited studies investigated the usefulness of additional posterior and right ventricular (RV) leads during PCI.[2-4] However, a comprehensive description of the ST-segment changes on the 18-lead ECG, including RV and posterior leads, during controlled coronary artery occlusion has not been fully undertaken. Therefore, this study quantified ST-segment changes on the 18-lead ECG during PCI in each of the 3 major coronary arteries and compared the sensitivity in detecting acute myocardial ischemia using routine cardiac monitoring leads (II and V_1), 12-lead ECG, and 18-lead ECG.

Materials and methods

Sample and setting

The study presented in this article included 155 subjects with coronary artery disease who underwent a nonemergent cardiac catheterization to either a community hospital or 1 of 3 academic medical centers. Of the 155 subjects, the left anterior descending coronary artery (LAD) was involved for 58 (37%) subjects, the right coronary artery (RCA) for 44 (28%) subjects, and the left circumflex coronary artery (LCX) for 53 (34%) subjects. Percutaneous coronary intervention in the proximal RCA, before the RV branch, occurred in 43% of the subjects with RCA occlusions. Percutaneous coronary intervention in the proximal LAD coronary artery, before the first diagonal branch, occurred in 48% of the subjects with LAD occlusions. Subjects having an acute myocardial infarction (MI) at the time of PCI were

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excluded because of the difficulty in distinguishing balloon inflation–induced ST-segment changes from ST changes with an evolving acute MI. Informed consent was obtained from the subjects in a manner as approved by each institution's Committee on Human Research.

Instruments and procedure

Continuous 18-lead ECGs were recorded beginning when the subject entered the catheterization laboratory and throughout the entire procedure. The 18-lead ECGs were recorded using 2 Mortara ELI 100 ST monitors (Mortara, Milwaukee, Wis). One monitor recorded the standard 12-lead ECG, whereas the second monitor recorded posterior leads V_7 through V_9 and RV leads V_3R through V_5R. The ELI 100 ST monitor was a portable, programmable, microprocessor–based device that acquired, analyzed, and stored 12-lead ECGs at programmed intervals. In this study, the monitors were programmed to analyze and store the ECGs every 20 seconds during the coronary intervention procedure. The monitors were time-synchronized and programmed identically with filter settings of 0.05 to 100 Hz, as recommended for ST analysis by the American Heart Association.[5] In accordance with standards used for clinical practice, a calibration of 10 mm/mV and a paper speed of 25 mm/s were used. The monitors were programmed to measure the ST segment at J + 60 milliseconds using the PR segment as the isoelectric reference point. Baseline ECGs were obtained before the controlled balloon occlusions for comparison purposes. Radiolucent ECG wires and electrodes were used to minimize interference with visualization of the coronary arteries.

At the end of each monitoring session, the stored ECGs were downloaded to a personal computer with an additional ST-segment analysis software (Mortara ST Review Station, Mortara). The ST Review Station provided quantitative ST-segment measurements in microvolts for each of the 18 leads. Any "noisy" ECGs were eliminated according to established procedures.[6] To determine the timing of balloon inflation and deflation, we continuously recorded the "real-time" standard 12-lead rhythm strips during the procedure with a Hewlett-Packard Pagewriter XLI Cardiograph (Hewlett-Packard, McMinnville, Ore).

ST amplitudes at the preinflation baseline were subtracted from the maximum ST amplitudes during balloon inflation to create a positive or negative change score (ΔST) for each of the 18 leads. The term *ΔST elevation* was used to describe a change in the ST-segment level in the positive direction from the baseline, whether or not actual ST-segment elevation from the isoelectric line was present. The term *ΔST depression* was used to describe a change in the ST-segment level in the negative direction from the baseline, whether or not actual ST-segment depression from the isoelectric line was present. This ΔST value was used to ensure that only "new onset" ST-segment deviation was considered. Ischemic changes were defined as a ΔST of 1 mm (100 μV) or greater in any of the standard 12 leads or RV leads [7], or 0.5 mm (50 μV) or greater in any of the posterior leads [2]. Because posterior leads are further away from the heart than the anterior precordial leads, the recordings in these posterior leads were often small in voltage and the ST-segment elevation could be subtle. The use of 0.5-mm criterion in the posterior leads has been suggested by prior work in patients undergoing LCX occlusions[2] and in patients with acute MI.[8] The ischemic ST changes occurred with balloon inflation and disappeared after a brief period of balloon deflation.

Statistical analysis

Each patient served as his/her own control. Sample characteristics were analyzed using frequencies and measures of central tendency. Mean ΔST changes for each major artery during PCI were reported. The sensitivity of each ECG lead for detecting PCI-induced ΔST elevation and depression was expressed as a proportion representing the number of subjects with evidence of ischemia divided by the total number of subjects. Differences in sensitivity in detecting acute myocardial ischemia among the routine monitoring leads (II + V_1), standard 12-lead ECG, and 18-lead ECG were compared using analysis of variance. A P value of less than .05 was considered statistically significant.

Results

Sample characteristics

The mean age of the subjects in the LAD, RCA, and LCX groups were 64 ± 11, 68 ± 11, and 68 ± 11 years, respectively. Seventy percent of the subjects were men. Ethnicity included whites (60%), Asian Americans (17%), Hispanics (15%), African Americans (6%), and Native Americans (2%). The mean duration of the balloon occlusion for the inflations selected for analysis was 65 seconds. None of the subjects in any of the coronary artery groups had a ventricular pacing rhythm, an RV hypertrophy, or Wolff-Parkinson-White syndromes. Subjects with right or left bundle branch blocks were included in the analysis because ST changes could be identified using the ST-segment trend.

Quantitative ST-segment changes

The ST-segment changes on each of the 18 leads during occlusion of the 3 major coronary arteries were analyzed quantitatively. Data from this study showed that ST-segment elevation was often present in the anteroapical (V_1 through V_6), lateral (I and aVL), and RV lead V_3R during LAD occlusions; in the inferior (II, III, and aVF), RV (V_3R through V_5R), and posterior leads (V_7 through V_9) during RCA occlusions; and in the posterior, inferior, and apical leads (V_5 through V_6) during LCX occlusions. The average ST-segment deviation for each ECG lead on all patients is presented in Fig. 1. During occlusion of the LAD coronary artery, the maximum ST-segment elevation averaged 4.22 mm for lead V_3, followed by lead V_4 (4.03 mm) and V_2 (3.36 mm). During RCA occlusion, the maximum ST-segment elevation was an average of 2.23 mm for lead III, 1.94 mm for lead aVF, and 1.65 mm for lead II. During LCX occlusion, the maximum ST-segment elevation averaged 0.8 mm for lead V_7, 0.76 mm for lead V_8, and 0.75 mm for lead III. The mean ST elevation for posterior lead V_9 was 0.59 mm.