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Ischemia-induced repolarization response in relation to the size and location of the ischemic myocardium during short-lasting coronary occlusion in humans☆

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Abstract

Background: The ventricular repolarization (VR) response to short-lasting coronary occlusion has been characterized by 3-dimensional vectorcardiography (VCG) in humans; the T vector loop becomes distorted and more circular. The purpose of this study was to relate these changes to the size of the myocardium at risk (MAR) and its location.

Methods: Continuous VCG was applied during transient coronary occlusion in 35 elective angioplasty patients, and the size of the MAR was estimated by single-photon emission computed tomography. Three VR aspects were assessed at baseline vs maximum ischemia: the ST segment, the T vector angles, and the T vector loop morphology.

Results: The T loop morphology changes were significantly associated with MAR size, but also dependent of its location. In contrast, the early phase of VR reflected by the ST segment responded to acute ischemia in relation to the MAR size independent of location.

Conclusion: The VR changes were related both to the size and the location of the MAR and most pronounced during occlusion of the left anterior descending artery.

Keywords: Ventricular repolarization; Sudden cardiac death; Coronary artery; Vectorcardiography; Acute ischemia

Introduction

Sudden cardiac death (SCD) usually occurs in a setting of coronary artery disease (CAD).[1] The amount of ischemic myocardium and the heart rate are crucial factors determining the occurrence of ventricular arrhythmias during experimental acute myocardial ischemia.[2] The relation between these factors and relevant electrophysiologic alterations is less clear, as is the situation in humans, although a wealth of data concerning the profound electrophysiologic consequences of abrupt ischemia is available.[3] Abnormal ventricular repolarization (VR) has emerged as one important electrophysiologic factor predisposing for malignant ventricular arrhythmias and SCD in congenital and acquired conditions.[3-5]

Apart from the duration of VR, that is, the QT interval on the standard electrocardiogram (ECG), and ST-segment analysis, assessment of other aspects of VR is not easily obtained noninvasively in humans. Three-dimensional (3-D) vectorcardiography (VCG) has been proposed as an alternative tool[6] and has by us been applied in humans to follow the VR response to acute ischemia during angioplasty, pacing-induced ventricular remodeling ("cardiac memory"), and "cardiac fatigue."[7-11] T vector and T vector loop analysis has been applied to study VR from the J-point to Tend. A consistent pattern has been observed in response to short-lasting ischemia in humans with a distorted and more circular T vector loop compared with baseline. These alterations have

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recently been correlated to the occurrence of ventricular fibrillation (VF) in a porcine occlusion-reperfusion model, where distortion of the T vector loop (increased Tavplan) and increased heart rate preceded VF.[12]

Because the outcome after acute myocardial infarction (MI) has been related to the infarct size,[13] we hypothesized that the amount of threatened myocardium (myocardium at risk [MAR]) might be one important determinant for VR alterations during ischemia in humans.[14] The primary goal of the present study was therefore to explore the relationship between ischemia-induced global VR changes and the MAR size and its location during an elective angioplasty in patients with stable CAD. We focused on the entire VR phase as characterized by VCG-based T vector and T vector loop parameters.

Methods

Patients

Thirty-five patients with stable CAD scheduled for elective angioplasty were part of a study of single-photon emission computed tomography (SPECT)–estimated MAR and its relation to changes in the ST-segment vector magnitude (ST-VM and ST change vector magnitude [STC-VM]; for definitions, see below).[14] The study was approved by the local Ethics Committee, and informed consent was obtained from all participants. Exclusion criteria were chronic atrial fibrillation, bundle-branch block, MI, or pacemaker rhythm. For the present study on VCG parameters, 10 patients in the original study of 45 were excluded, 7 with ECG signs of previous MI, 1 who developed atrial fibrillation during angioplasty, and 2 with technically unsatisfactory recordings.

Angioplasty and SPECT

The angioplasty procedure was performed according to routine. Fifteen seconds after the start of the first balloon inflation, 900 MBq (1-2 mL) technetium Tc 99m sestamibi (Cardiolite; Du Pont Scandinavia, Stockholm, Sweden) was injected intravenously; and SPECT imaging was started approximately 1 hour later. The duration of the balloon inflation was decided by the responsible interventionist and influenced by chest pain and the extent of ST changes during ischemia. The image acquisition technique, including the construction of a volume-weighted bull's-eye plot applying the CEqual algorithm (General Electric Medical System, Milwaukee, WI), has been described previously (Fig. 1).[14,15] Briefly, each short-axis tomogram (slice) was compared with a slice from a reference group. This consisted of patients with less than 5% likelihood of CAD based on a sequential Bayesian analysis of age, sex, symptom classification, and the results of an exercise ECG. The percentage of abnormal pixels was calculated. Myocardium at risk was expressed in percentage of the estimated size of the left ventricle (LV). The limit of abnormality varied between 1.75 standard deviations (SDs) below the mean normal profile for inferior defects and 3.75 SDs below the mean normal profile for lateral defects. The sensitivity of this method is 89%, and the normalcy rate (true negative rate in low-likelihood patients) is 81%.[16] The severity of the perfusion defect was calculated to reflect both its degree and its extent. It was defined according to Berman et al[17] by the sum of the product of all profile points with an uptake below the normal limits multiplied by their respective number of SDs below the normal mean count.

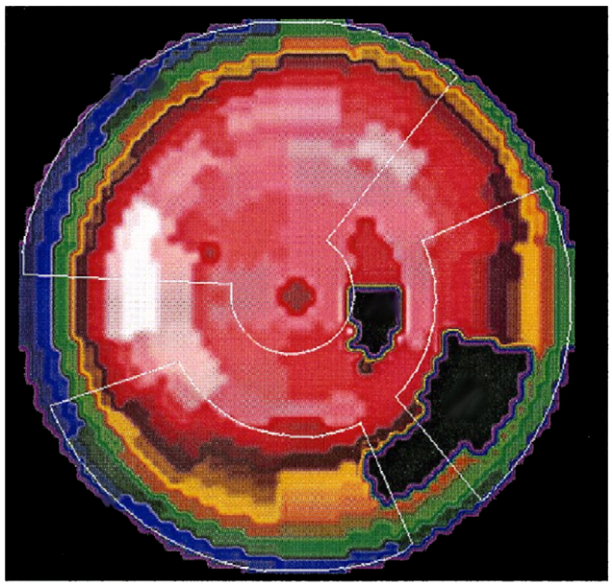

Fig. 1. Representative 2-dimensional polar map, which shows a perfusion defect during occlusion of the left circumflex artery.

3-D VCG recording and analysis

The VCG recording and analysis procedures have been described in detail elsewhere[7-11]; for illustrations, see Sahlén et al.[11] In brief, continuous VCG recording was initiated 10 minutes before angioplasty and until its completion using MIDA 1000 or CoroNet (Ortivus, AB, Danderyd, Sweden). Eight electrodes were positioned according to the orthogonal Frank lead system. The sampling frequency was 500 Hz; and the sampling period (here = time resolution of the pathophysiologic events) was 15 seconds, from which an averaged 3-D QRST complex was constructed. The maximum QRS and T vectors as well as the T vector loop (from here: T loop) in space were constructed from the average of all normal cardiac cycles during the sampling period.

Two conventional VCG parameters were used as reference: the ST-VM, which expresses the ST-segment deviation from the isoelectric level 60 milliseconds after the J-point, and the STC-VM, which is the spatial difference vector between the initial and current ST vector.

The direction of the maximum T vector in 3-D space was expressed by T vector elevation (Tel) and azimuth (Taz); and its relation to the maximum QRS vector, by the QRS-T angle.

The T loop is normally elongated (elliptical) and oriented in one plane, the "preferential plane." It was characterized by 2 parameters: (1) Tavplan is a measure of the mean distortion of the T loop from the preferential plane expressed in microvolts. A higher value of Tavplan means a more abnormal, that is, more bulgy (less planar) loop. (2) Teigenvalue (unitless) describes the form and geometry of