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Frequency of diastolic third and fourth heart sounds with myocardial ischemia induced during percutaneous coronary intervention

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Abstract

Background: Although the standard 12-lead electrocardiogram (ECG) is considered the gold standard to diagnose acute myocardial ischemia, nearly half of ECGs are nondiagnostic in patients who present with chest pain and have subsequent confirmation of infarction with positive serum biomarkers.

Methods: A prospective study was performed to investigate the frequency and intensity of diastolic third and fourth heart sounds (S3 and S4), as measured by computerized acoustic cardiography, with myocardial ischemia induced by balloon occlusion during percutaneous coronary intervention.

Results: In our 24 subjects, during percutaneous coronary intervention–induced ischemia, a new or increased intensity S3 or S4 developed in 67%. Ten (67%) of 15 patients without clinical ST criteria for ischemia also developed new or increased-intensity diastolic heart sounds.

Conclusions: The combined use of diastolic heart sounds, as a measurement of ventricular dysfunction, with the standard ECG may improve the noninvasive diagnosis of myocardial ischemia that is likely to develop into infarction.

Keywords: Myocardial ischemia; Acoustic cardiography; Phonocardiography; Heart sounds; Electrocardiography

Introduction

In patients with acute coronary syndrome, early detection of myocardial ischemia is crucial in preventing myocardial cell death because it enables patients to receive early medical therapy or percutaneous coronary intervention (PCI). The standard 12-lead electrocardiogram (ECG) is the cornerstone for the early detection of myocardial ischemia that is likely to develop into acute myocardial infarction (MI). However, the standard ECG is nondiagnostic in about one half of acute MIs that are later confirmed with positive biomarkers.[1-2]

Ventricular dysfunction during myocardial ischemia and infarction has been frequently observed. Investigators have demonstrated abnormal wall motion in the ischemic myocardial zone on echocardiography[3] and a rise in left ventricular end-diastolic pressure (LVEDP) as measured by pulmonary artery catheter monitoring[4-5] or direct measurement of ventricular pressure,[6-7] reflecting reduced contractility and/or compliance of the myocardium. Also, a few animal study results[8-9] suggest that, without ST changes, ventricular function may be impaired during repeated PCI balloon occlusions, inducing “stunning of the myocardium.” However, traditional measurements of ventricular function are impractical in clinical settings because they require an invasive procedure or are not available when a patient experiences transient ischemia. Moreover, they do not provide continuous monitoring of the dynamic process of ischemia that develops into infarction.

Acoustic cardiography is a new noninvasive measure of ventricular function that incorporates the principles of phonocardiography to detect diastolic heart sounds.[10-12] Diastolic third and fourth heart sounds (S3, S4) have been shown to be strongly associated with elevated LVEDP and abnormal wall motion in myocardial ischemia[13-14] as well as in other heart diseases.[10-12] The prevalence of diastolic heart

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sounds during acute MI[14-18] and myocardial ischemia[19-21] was investigated in the 1960s and 1970s using cumbersome phonocardiographic instruments of that era or human auscultation, which has proven to be unreliable and impractical.[22-23] A noninvasive measure of abnormal ventricular function that could be readily applied and continuously monitored for real-time clinical decision-making may provide diagnostic information about ischemia/infarction that is independent of the heart's electrical activity.

Previous studies of diastolic heart sounds have limitations including (*a*) most studies have been conducted with acute MI[14-18] and not ischemia, (*b*) preexisting diastolic heart sounds were not considered and thus an increased intensity of preexisting diastolic heart sounds was not measured, and (*c*) the prevalence of diastolic heart sounds in myocardial ischemia has only been reported during exercise,[19-21] which reflects the model of "demand-related" ischemia. In contrast, the PCI-induced ischemia model used in the present study provides more accurate information about the frequency and significance of diastolic heart sounds during ischemia due to coronary occlusion.

The purpose of this study was to determine whether new or increased intensity diastolic heart sounds, as measured by computerized acoustic cardiography, occur more frequently during myocardial ischemia induced by PCI than at baseline before the procedure.

Methods

Research design, sample, and setting

A prospective, observational study was conducted in the adult cardiac catheterization laboratory at the University of California, San Francisco. A convenience sample of patients undergoing nonurgent diagnostic coronary angiography with possible PCI was enrolled. Excluded from the study were patients with acute ST-elevation MI receiving primary PCI or with other hemodynamically unstable situations requiring urgent cardiac catheterization. Also excluded were patients without an ability to develop an S4 (atrial fibrillation or flutter), patients likely to have diastolic heart sounds due to nonischemic conditions (ie, severe valvular heart disease, anemia, pregnancy, thyrotoxicosis, atrioventricular shunt, or tachycardia >120 beats/min), and patients with paced rhythm, as well as non–English-speaking patients. However, patients with ECG confounders for ischemia (eg, bundle-branch block, left ventricular hypertrophy [LVH]) were not excluded from the study. The study was approved by the institution's Committee on Human Research, and written informed consent was obtained before cardiac catheterization.

Instruments

Computerized acoustic cardiography

The Audicor system (Inovise Medical Inc, Portland, OR) has been approved by the US Food and Drug Administration and is commercially available. The system includes an electrocardiograph, 2 dual-purpose ECG/heart sound sensors, and a computerized device to interpret the heart sound data. The disposable dual-purpose sound sensors are substituted for the electrodes placed in the V_3 and V_4 locations (Fig. 1). The use of 2 sound sensors in 2 locations increases the likelihood of detecting diastolic heart sounds because if sounds from one channel are inadequate, then the algorithm can use the alternate sensor. In the present study, a Hewlett Packard XLi cardiograph (Philips, Andover, MA) was used to record 12-lead ECGs at a sampling rate of 1000 Hz. Acoustic and ECG data were recorded continuously before and during the cardiac catheterization and PCI procedures and stored for off-line analysis.

The acoustic cardiographic system's computer algorithm identifies normal and extra heart sounds by the timing of heart sounds relative to ECG waveforms and by the characteristics (ie, frequency, amplitude) of the sounds. Sounds with the appropriate characteristics that consistently occur at the proper time for an S3 or S4 are rated from 0 to 10, with 10 as the most intense and persistent value. The algorithm diagnoses the presence of an S3 or S4 when the intensity exceeds a value of 5. The algorithm for detecting diastolic heart sounds has been validated in prior studies comparing the detection of S3 and S4 to hemodynamic parameters obtained during cardiac catheterization.[11] Also, its validity has been reported in a study correlating diastolic heart sounds with tissue Doppler imaging, echocardiography, and B-type natriuretic peptide levels.[12]

Procedure

A research nurse dedicated solely to the study gathered all data before and during cardiac catheterization and PCI. The 12-lead ECG and acoustic cardiographic system were attached with torso-positioned limb leads in the standard Mason-Likar configuration.[24] A small device was attached to the acoustic cardiographic system that produced a temporary flat line segment on the V_3 or V_4 ECG lead when a switch was depressed. This allowed the research nurse to mark precise

Fig. 1. Placement of acoustic cardiographic sensors. Acoustic cardiographic sensors are substituted for the V_3 and V_4 electrodes when recording a standard 12-lead ECG. These special sensors acquire acoustic as well as ECG data. For the present study, in women with pendulous breasts, the acoustic cardiographic sensors were placed under the breast tissue and affixed to the chest wall.