Real time assessment of myocardial revascularization during coronary artery bypass surgery by means of ultrasonic integrated backscatter

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Abstract

Objective: The recovery of cyclic variation (CV) of ultrasonic integrated backscatter (IB) may provide a more sensitive predictor of the success of myocardial revascularization. This study was designed to elucidate the possibility of real time assessment of coronary artery bypass grafting (CABG) using CV of IB. Methods: We studied 10 patients (61 ± 4 years old) with the perfused areas by stenosed or occluded LAD without myocardial infarction. There were six ischemic dysfunctional areas, and four ischemic but non-dysfunctional areas. The CV of IB was measured before and just after extracorporeal circulation (ECC). Wall motion was analyzed by segmental wall thickening during systole at the same time of the IB analysis during CABG and at 3 weeks after CABG. Those 10 areas were completely revascularized. Results: In the non-dysfunctional areas, wall thickening did not change and remained at normal values before and after ECC, and 3 weeks after CABG (31 ± 3% 29 ± 3% and 29 ± 5%, respectively). The magnitude of CV of IB did not also change before and after ECC (8 ± 1 dB and 7 ± 3 dB). However, in the ischemic dysfunctional areas, while wall thickening did not change before and after ECC (21 ± 5% and 20 ± 5%), it increased and reached similar values as the non-dysfunctional regions at 3 weeks after CABG (26 ± 7%, P < 0.01 vs. before and after ECC values). The magnitude of CV of IB increased even after ECC (3 ± 71 ± 4 dB vs. 7 ± 3 dB, P < 0.05), and reached the same level as those in the non-dysfunctional areas. There was a significant relationship between wall thickening at 3 weeks after bypass grafting and magnitude of CV of IB after ECC (r = 0.67, P < 0.05). Conclusions: Improvement in wall motion was gradually attained after bypass grafting. On the contrary, an increase in the magnitude of CV of IB was obtained immediately after myocardial revascularization. Our data suggest that CV of ultrasonic IB method can provide close real time information regarding the effectiveness of bypass surgery. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

It has been previously demonstrated that the assessment of the effectiveness of myocardial revascularization can be made by wall motion analysis. However, it usually takes time to see the recovery in wall motion, which improves gradually. In the clinical setting particularly in the operating room, it is requested to see the real time changes or very rapid effect of myocardial perfusion. It has been reported that the recovery of cyclic variation (CV) of ultrasonic integrated backscatter (IB) shows more sensitive reflection of the recovery of regional intramural contractile performance than the wall motion analysis in acute myocardial infarcted areas [1–3]. We postulated that the recovery of CV of ultrasonic IB may provide a sensitive predictor of the success of myocardial revascularization even in ischemic dysfunctional areas including hibernating myocardial areas. Moreover, the application of this method during coronary artery bypass grafting (CABG) may enable intraoperative real time assessment.

In the present study, we designed an experiment to evaluate hibernating myocardial areas preoperatively and then elucidate the possibility of real time assessment of CABG using ultrasonic IB.

2. Patients and methods

2.1. Patient selection

We studied 10 patients with perfused areas by stenotic or occluded LAD without myocardial infarction. They consisted of three females and seven males (mean age...
61 ± 4 years old). We divided those 10 areas perfused by LAD into six ischemic dysfunctional areas and four ischemic but non-dysfunctional areas. Myocardial infarction is defined by the electrocardiogram changes and a routinely preoperatively performed dobutamine stress echocardiogram. Informed consent for the procedure was obtained from all the patients.

2.2. Acoustic densitometry

We used a special software package (Acoustic Densitometry) developed by Hewlett-Packard (Andover, MA) incorporated in a commercially available SONOS 2500 system (Hewlett-Packard). This system is capable of providing either conventional echocardiographic images or two-dimensional images in which gray levels are displayed proportional to IB amplitude. Sixty frames from consecutive cardiac cycles (30 frames/s) are displayed after scan conversion and are stored on the optical disk. When operating in the IB imaging mode, the received ultrasound signal is amplified, mixed to an appropriate intermediate frequency, phased, and delayed [4].

2.3. Study protocol

All patients underwent a transesophageal echocardiographic examination before and just after termination of extracorporeal circulation (ECC) when hemodynamics became stable during CABG. The short-axis view at the papillary muscle level of the left ventricle was recorded on an optical disk using an electrical sector scanner equipped with acoustic densitometry (carrier frequency 2 MHz). We depicted two-dimensional IB images and the 60 digital frames (2 s) were transferred to the optical disk. The transmit power, compression setting and individual values of the time gain compensation were kept constant throughout the IB studies.

2.4. Data analysis

Only digitally acquired images can be analyzed with this acoustic densitometry package. Time-intensity waveforms for IB were determined in the reconstructed frames. The position of the region of interest (ROI) was decided in the perfused areas of LAD (= anterior wall) and the size of the ROI was chosen as large as possible (which excluded endocardial and epicardial reflectors). A single observer adjusted the location of the site on a frame-by-frame basis to keep it well within the myocardial midwall throughout the cardiac cycle. The ultrasonic IB versus time curve was then reconstructed. We used a moderate mode of curve fitting for smoothing the time-amplitude waveform.

The magnitude of CV of ultrasonic IB was determined as the difference between the minimal and maximal values in the cardiac cycle, averaged over at least two consecutive beats. Absolute calibration of the imaging system was not required to measure the CV of IB.

2.5. Evaluation of regional wall motion

In order to quantitatively assess the regional wall motion in the reperfused areas, the percentage increase in segmental wall thickening during systole was used in the same transeophageal echo image (short-axis view of the papillary muscle of the left ventricle) of the acoustic densitometry. After tracing of the endocardium and epicardium, wall thickness was measured at the center of the segment on the end-systolic and end-diastolic images, and percentage increase in segmental wall thickening during systole was calculated. This evaluation of regional wall motion was performed 3 weeks after CABG using transthoracic echocardiography.

We evaluated that the values of the percentage increase in segmental wall thickening during systole are under 25% (as for preoperative dysfunctional areas). The regional wall motion was assessed with no administration of catecholamine for the maintenance of hemodynamics after myocardial revascularization.

2.6. Reproducibility of results

Intraobserver and interobserver variability was determined by measuring the magnitude of CV of ultrasonic IB. The intraobserver correlation was \( y = 1.03x - 0.50 \) \((r = 0.98)\), and the interobserver correlation was \( y = 0.99x - 0.43 \) \((r = 0.98)\).

2.7. Statistical analysis

All data are expressed as the mean ± SD. Individual data were compared by non-parametric Wilcoxon method. Differences were considered significant at \( P < 0.05 \).

3. Results

3.1. Changes of wall motion before and after myocardial revascularization

In the ischemic but non-dysfunctional areas, wall thickening during systole did not change and remained at normal values before ECC, after ECC, and at 3 weeks after CABG (31 ± 3% vs. 29 ± 3% and 29 ± 5% respectively). In the ischemic dysfunctional areas, wall thickening did not improve just after ECC (before vs. after; 21 ± 5 vs. 20 ± 5) but improved and reached the values of the non-dysfunctional areas at 3 weeks after CABG (26 ± 7%; \( P < 0.05 \)). Wall thickening at 3 months after bypass grafting 28 ± 5% (Fig. 1).

3.2. The changes in the magnitude of CV of ultrasonic IB before and after myocardial vascularization

In the ischemic but non-dysfunctional areas, the magnitude of ultrasonic IB did not change before and after ECC (8.0 ± 1.6 dB vs. 7.8 ± 1.3 dB). However, in the ischemic
dysfunctional areas, the magnitude of ultrasonic IB increased just after ECC (3.7 ± 1.4 dB vs. 7.4 ± 3.5 dB, \( P < 0.02 \)) and reached the values of the ischemic but non-dysfunctional areas (Fig. 2).

3.3. Relationship between wall motion and magnitude of CV of ultrasonic tissue characterization

There was a significant relationship between wall thickening at both 3 weeks and 3 months after CABG and magnitude of CV of ultrasonic IB after ECC (\( r = 0.67 \) and \( r = 0.76, P < 0.05 \) and \( P < 0.02 \)) (Fig. 3), which suggested that the regional wall motion in the late stage after CABG is predicted by the magnitude of CV of IB just after myocardial revascularization during CABG.

4. Discussion

The present study revealed that this new method by means of ultrasonic IB might enable not only close real time assessment of coronary revascularization during CABG, but also preoperative evaluation of hibernation myocardium. The recovery of CV of ultrasonic IB more sensitively reflects the recovery of regional intramural contractile performance than does wall motion.

Milunski et al. [1] also reported that ultrasonic IB enabled earlier identification of the effectiveness of myocardial revascularization than did wall motion analysis in acute myocardial infarction in dogs [1]. Other studies have shown that the magnitude of CV of ultrasonic IB defined the severity of ischemic injury after experimentally induced coronary artery occlusion and reperfusion in dogs, and may be able to discriminate viable (stunned) from irreversibly injured tissue [2,3]. Our data suggest that this new method may be able to be applied in chronic ischemic regions.

Patients with remote myocardial infarction have a significantly depressed CV in their infarcted zones compared with regions that manifest normal functions [5]. The present study found that even in hibernating myocardium the magnitude of CV of IB showed to be lower, and the magnitude in the hibernating myocardial areas recovered just after myocardial revascularization. We think that this method enables preoperative assessment of the hibernating myocardium in the dysfunctional areas.

Ultrasonic IB is still not fully understood in terms of its mechanism. Wickline [6] assigned the time-varying acoustic impedance of the intracellular myofibril-sarcomere assembly to one of the two interfacing zones that are hypothetically responsible for backscatter. They hypothesized that sarcomere shortening would cause a relative increase in intracellular acoustic impedance and a corresponding reduction in the impedance mismatch between the two interfacing media [6]. The mechanism of immediate increase of the magnitude of ultrasonic IB in the hibernating areas found in the present study is unclear. The increase of blood flow to the hibernating areas may bring out sarcomere shortening. The data indicate that the CV of IB, which is independent of heart rate, mean arterial pressure, preload, and inotropic state [7], provides information characterizing regional contractile function that is not available from the analysis of wall thickening alone.
The clinical implication of this study is to assess the efficacy of myocardial revascularization including anastomotic complication intraoperatively. Since the magnitude of CV of IB is greater after myocardial revascularization, we predict that wall motion would be good in the late stage.

In conclusion, this relatively new approach can provide a sensitive index of the success of reperfusion after pharmacological or mechanical interventions in patients, and the analysis of CV of ultrasonic IB can provide real time information regarding the effectiveness of CABG.

References