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Myocardial Electrical Impedance Correlates with Ischemic ECG ST-Segment Changes in Humans

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Abstract—**Electrocardiogram (ECG) ST-segment changes are commonly used to diagnose myocardial ischemia. In this study we compared ST-segment changes with changes in myocardial electrical impedance (MEI) - an electrical parameter that also responses to ischemia - during off-pump coronary artery bypass graft (OPCABG) surgery of the left anterior descending coronary artery (LADa). We recorded MEI and ST-segment changes in eight patients during OPCABG surgery and compared the change in MEI that occurred when the LADa was occluded just prior to the beginning of the revascularization procedure with the ST-segment changes during the same period. Myocardial electrical impedance changes were directly and significantly correlated with ST-segment changes in our patient population. Our results indicate that MEI is equivalent to ST-segment changes as a measure of myocardial ischemia.**

I. Introduction

In this laboratory, we developed a practical method for measuring myocardial electrical impedance (MEI) [1] and have used it to study myocardial ischemia and reperfusion in several animal species including human clinical patients [2-4]. Myocardial electrical impedance has been found by us [2,3] and other researchers to increase predictably with myocardial ischemia. This increase has been proven to be well correlated with the functional [4], ionic and metabolic state of the myocardium. In this study we compared ischemic ECG ST-segment changes with MEI changes in humans undergoing off-pump coronary artery bypass graft (OPCABG) surgery of the left anterior descending coronary artery (LADa).

II. Materials and Methods

After obtaining FDA and institutional approval as well as informed written patient consent, we recorded MEI and ECG ST-segment changes in eight patients undergoing OPCABG surgery [2,3,5] on their LADa. Myocardial electrical impedance was recorded in a fashion previously described [2-5]. Our MEI monitor consists of a laptop computer that communicates with and controls custom analog circuitry that, in turn, connects to the heart via two temporary pacing electrodes (MYOWIRE size 2-0 [3.0 metric] temporary cardiac pacing wires, A&E Medical Corporation, Farmingdale, NJ) attached to the myocardium approximately 1 cm apart in the region of the heart fed by the LADa. A 5-μA 100μs impulse is impressed on the myocardium and the current impulse and resultant voltage drop across the myocardial tissue between the electrodes are measured, amplified, filtered, digitized at 22.0kHz 12-bit resolution and transformed into the frequency domain via Fourier transformation. Myocardial electrical impedance is calculated by dividing the associated resultant voltage component by the impressed current component at each frequency interval and then averaging the impedance over the impedance spectrum from 270Hz to 5.9kHz with a 5.3711Hz frequency domain resolution.

Electrocardiogram ST-segment changes were measured and calculated with a General Electric Solar 8000M (GE Healthcare Technologies, Waukesha, WI) operating room patient monitor. ST-segment variations were measured in the inferior and lateral ECG leads. The absolute values of the ST-segment variation in these two leads were summed, as described by Ellis et al. [6] to arrive at the overall ST-segment elevation used for our comparison with MEI changes.

Myocardial electrical impedance and ECG ST-segment measurements were made on our eight patients just prior to and following LADa occlusion before the LADa revascularization procedure began. Since the patient's LADa was not 100% stenosed, this gave us the opportunity to measure the effects of induced ischemia when the LADa was occluded by the surgeon in preparation for the surgery. The difference between MEI before and after occlusion, and the difference between ST-segment measurements before and after occlusion, were calculated and plotted against each other. We performed correlation and regression analyses taking MEI as the dependent variable and ECG ST-segment changes as the independent variable. We calculated the significance of the correlation between MEI and ECG ST-segment measurements. Statistical significance was set *a priori* at $p<0.05$.

III. Results

We found a significant direct linear correlation ($R^2=0.8546$) between MEI and ECG ST-segment changes in our eight patients (Fig. 1). As seen in the figure, the relationship between ECG ST-segment changes and MEI changes is well modeled by a first-order polynomial function. In this small sample of patients we did not find a relationship between MEI changes at LADa occlusion and LADa stenosis as determined from cardiac catheterization (Fig. 2) although this relationship did exist in a previous larger patient study.

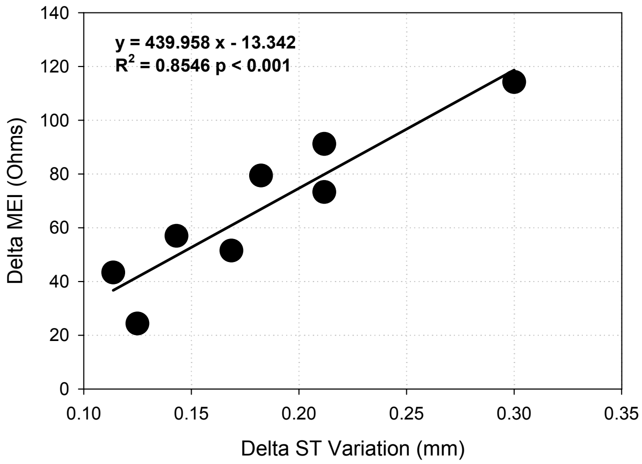

Fig. 1. Delta MEI vs Delta ST variation in eight patients undergoing LAD revascularization.

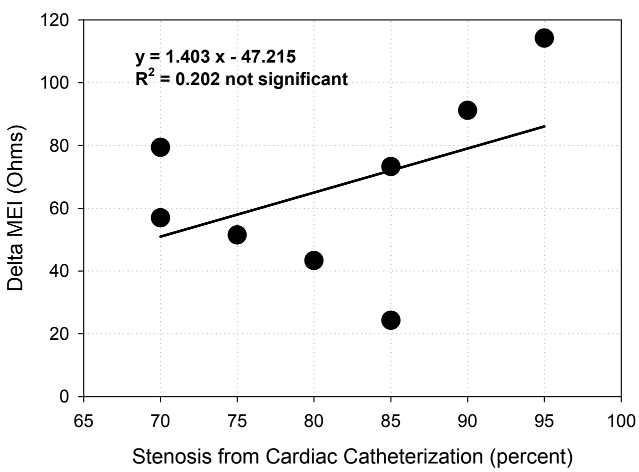

Fig. 2. Delta MEI vs LADa Stenosis in eight patients undergoing LAD revascularization.

IV. Discussion

In this study we compared MEI changes with ECG ST-segment changes in patients undergoing OPCABG revasularization of the LADa. Occlusion of the LADa prior to the surgery induces myocardial ischemia in the LADa distribution region of the heart. Under these conditions, we found that a relationship does, in deed, exist between MEI and ECG ST-segment changes. The increase in MEI exhibited at LADa occlusion is directly correlated with ST-segment changes.

As shown by Cinca et al. [7] in a pig model, myocardial ischemia impairs the active electrical cell properties that create membrane potential differences between the ischemic and normal zones. Ischemia leads to cell-to-cell uncoupling which not only increases MEI but also leads to ST-segment elevation. In this small study we have demonstrated the relationship between MEI and ST-segment changes clinically in human subjects.

We were surprised not to see a relationship between MEI changes and the measured stenosis of the LADa from cardiac catheterization. In a previous larger study a significant relationship did exist between these parameters [3]. It may be that our small patient sample was inadequate to detect this relationship.

References

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