Seismocardiography for Monitoring Changes in Left Ventricular Function during Ischemia*

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Seismocardiography is a new noninvasive technique for recording cardiac vibrations. Changes in the recorded waves have been correlated with acute and chronic changes in left ventricular function. In this report, we describe a patient who developed ischemia induced by coronary angiography in the cardiac catheterization laboratory. The patient's seismocardiogram showed distinct changes during the ischemic episode that actually preceded the onset of symptoms and resolved after nitroglycerin therapy. The patient's seismocardiographic recordings were significantly different from the recordings from five control individuals. This observation suggests that seismocardiography may be helpful for monitoring left ventricular function during episodes of myocardial ischemia. (Chest 1991; 100:991-93)

Seismocardiography is a new noninvasive technique for recording cardiac vibrations.¹ Seismocardiography is a form of displacement cardiography, a field that includes apexcardiography, kinetocardiography, ballistocardiography,² and cardiokymography.³,⁴

A seismocardiogram is obtained by placing an ultra-low-frequency accelerometer on the sternum.¹ Recordings are obtained during quiet respiration. In healthy volunteers, we have found that the seismocardiogram remains stable over three months.¹ Ventricular pacing promptly and reversibly alters the shape of the seismocardiographic wave.¹ We have observed changes in these seismocardiograms during percutaneous transluminal coronary angioplasty¹,⁵ and immediately after exercise in patients with coronary artery disease.⁶ In this report, we describe the short-term changes of the seismocardiogram in a patient who developed ischemia and subsequent angina during cardiac catheterization and compare this patient's seismocardiogram to the recordings from five normal volunteers.

**Case Report**

A 52-year-old woman was undergoing cardiac catheterization for evaluation of episodic dyspnea and chest tightness. She had a history of hypertension, premature ventricular contractions, and depression. Her cardiac medications were disopyramide and aspirin. The patient had a grade 2/6 systolic murmur. Her resting electrocardiogram was normal, but an exercise thallium study showed 2 mm of ST-segment depression and a fixed apical thallium defect. Her echocardiogram demonstrated normal left ventricular function and mild mitral insufficiency.

We obtained a seismocardiogram during her initial right cardiac catheterization. Initially, the right atrial pressure was 6 mm Hg, the pulmonary artery pressure was 25/11 mm Hg, and the mean pulmonary wedge pressure was 12 mm Hg (Fig 1A). Following the coronary arteriograms, we obtained a second seismocardiogram during aortic pressure measurements. We noted on the oscilloscope that the wave morphology of the seismocardiogram was visibly changed compared to the initial recording. Although the patient denied any symptoms at the time, the pulmonary artery catheter was repositioned (after having been pulled back for angiography), and a second pulmonary wedge recording was obtained (Fig 1B). The mean pulmonary wedge pressure had increased to 25 mm Hg with prominent a (29 mm Hg) and v (39 mm Hg) waves. We then recorded left ventricular pressure at 156/13, 25, 32 mm Hg. The patient then reported feeling her typical symptoms of shortness of breath and chest tightness. She received two doses of 0.4 mg of nitroglycerin spray sublingually 2 min apart, with subsequent elimination of her symptoms and return of the pulmonary wedge pressure to baseline (mean, 9 mm Hg) (Fig 1C). We performed left ventriculography after her symptoms had subsided. The coronary arteriogram showed severe two-vessel coronary artery disease with 90 percent obstruction of the proximal circumflex and 75 percent obstruction of the proximal left anterior descending artery. Her left ventricular ejection fraction was 52 percent. There was trace mitral insufficiency and no left ventricular wall motion abnormality.

**Comparison with Normal Subjects**

Using M-mode and pulsed-wave Doppler echocardiography, we have previously shown that the seismocardiogram contains waves corresponding to the peak flow across the mitral valve during early rapid filling (RF) of the left ventricle and during atrial systole (AS).¹ The seismocardiogram also has a wave corresponding to isovolumic contraction of the left ventricle, with the point on the wave where it suddenly develops a negative slope coinciding with mitral valve closure (MC). The largest seismocardiographic wave is usually the point that corresponds with the peak flow across the aortic valve during rapid ventricular ejection (RE). These events are labelled in Figures 1 and 2.

For comparison to this patient, we obtained seismocardiograms from five randomly selected normal volunteers at baseline, 1 h later, and one day after

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AS = atrial systole; MC = mitral valve closure; RF = rapid ventricular ejection; RE = rapid filling

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wave (RE) as the reference point, since it is usually the largest and most consistent wave. The AS/RE, MC/RE, and RF/RE ratios are shown in Figure 3. These ratios were stable over one week in the volunteers.

The patient demonstrated a visible and significant increase in the RF wave after angiography that resolved after nitroglycerin. This increase in the RF wave preceded the onset of symptoms. The patient's isovolumic contraction (MC) wave was prominent at baseline, remained large after the coronary angiogram, and then decreased after nitroglycerin. Her RE wave increased after nitroglycerin. The patient's AS/RE ratio was higher than the volunteers at all times, showing only a slight decrease after nitroglycerin (Fig 3). Her RF/RE ratio was significantly larger than those of the volunteers after angiography, but almost normalized after nitroglycerin. Her MC/RE ratio was already increased before angiography, remained high after angiography, and normalized after nitroglycerin.

Figure 1. Simultaneous ECG, seismocardiographic (SCG), and pulmonary artery wedge pressure (Paw) recordings obtained during initial phase of cardiac catheterization (panel A), after coronary arteriography before onset of symptoms (panel B), and after nitroglycerin (panel C). Seismocardiographic waves are labelled that correspond to isovolumic ventricular contraction and mitral closure (MC), rapid ventricular ejection (RE), early rapid filling of ventricle (RF), and atrial systole (AS). Accentuation of a and V pressure waves in wedge tracing, and RF wave in SCG recording can be seen in panel B, with return to their baseline size in panel C. Also, MC wave is prominent in panels A and B relative to RE wave, but relationship of these waves is normal in panel C.

Figure 2. Seismocardiographic waves recorded from healthy volunteer over three months; MC, RE, RF, and AS waves are identified (see Figure 1 and text).
Table 1—Changes in Seismocardiographic Wave Amplitudes

<table>
<thead>
<tr>
<th>Wave and Interval</th>
<th>Volunteers (n = 5)</th>
<th>Patient</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RE wave</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recording 1 to 2</td>
<td>-9±21</td>
<td>-6±14</td>
<td>NS</td>
</tr>
<tr>
<td>Recording 1 to 3</td>
<td>-11±23</td>
<td>49±51</td>
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</tr>
<tr>
<td>RF wave</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recording 1 to 2</td>
<td>-13±47</td>
<td>86±50</td>
<td>0.0003</td>
</tr>
<tr>
<td>Recording 1 to 3</td>
<td>11±51</td>
<td>-23±15</td>
<td>NS</td>
</tr>
<tr>
<td>AS wave</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recording 1 to 2</td>
<td>-20±36</td>
<td>-6±43</td>
<td>NS</td>
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<tr>
<td>Recording 1 to 3</td>
<td>-15±34</td>
<td>31±74</td>
<td>NS</td>
</tr>
<tr>
<td>MC wave</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recording 1 to 2</td>
<td>-10±39</td>
<td>11±36</td>
<td>NS</td>
</tr>
<tr>
<td>Recording 1 to 3</td>
<td>-3±34</td>
<td>-80±7</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

*Data for volunteers represent means ± SD of five beats measured from each of five volunteers. Patient’s data represent mean ± SD from five beats. Recordings 1 to 3 were obtained at baseline and one hour and one day later for volunteers; and during initial wedge, wedge after coronary arteriography, and wedge after nitroglycerin for patient; p values compare changes in volunteers to patient by unpaired t-test (significant p<0.006 using Dunnett’s correction). NS, not significant.

DISCUSSION

Thus, in the patient described in this report, we found that the early diastolic filling (RF) wave was noticeably increased at the time of increased pulmonary artery wedge pressure and elevated left ventricular diastolic pressure. The isovolumic ventricular contraction (MC) wave was abnormal at baseline and worsened at the time of increased wedge pressure. The seismocardiographic changes probably were caused by ischemia induced by the coronary arteriogram, since the patient developed her typical symptoms at the time and since the changes resolved after nitroglycerin. It is possible that the patient’s baseline mild mitral insufficiency became more pronounced after angiography, somehow contributing to the seismocardiographic changes. We readily detected the changes in the seismocardiographic waves by qualitative observation of the real-time oscilloscopic display. Use of the ratios, RF/RE and MC/RE, quantified these observations and might facilitate detection of relative changes in the amplitudes of these waves. These changes preceded the patient’s symptoms and rapidly resolved with lowering the wedge pressure.

Our observations of this patient suggest that seismocardiography may be helpful for monitoring left ventricular function during myocardial ischemia. Also, the method may provide an easy noninvasive means for early detection of ischemia before the onset of electrocardiographic signs or symptoms.

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Salerno DM: Consultant; minority shareholder and stock option holder, Seismed Instruments.
Zanetti J: Employee, Seismed Instruments; minority shareholder and stock option holder.

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