Resting and Postexercise Phonocardiogram and Electrocardiogram in Patients with Angina Pectoris and in Normal Subjects

By Wilbert S. Aronow, M.D., Ronald R. Uyeyama, M.D., John Cassidy, M.D., and Joseph Nebolon, M.D.

SUMMARY
One hundred patients with angina and 100 normal subjects, mean age 51 years, had simultaneous phonocardiograms and electrocardiograms at rest and after a double Master's test. A fourth heart sound was present at rest in 43% of the patients and 14% of the normal subjects, and after exercise in 94% of the patients and 29% of the normal subjects. All patients and the normal subject who had a third heart sound at rest had a fourth heart sound at rest, and all who had a third heart sound after exercise had a fourth heart sound after exercise. Fifty-nine per cent of the patients and 4% of the normal subjects had an ST-segment shift ≥1.0 mm, and 67% of the patients and 6% of the normal subjects had an ST-segment shift ≥0.5 mm. After exercise, 97% of the patients and 30% of the normal subjects had a fourth heart sound or an ST-segment shift ≥0.5 mm.

Additional Indexing Words: Exercise Coronary heart disease Third heart sound Fourth heart sound

FOURTH and third heart sounds may occur in ischemic heart disease. We performed this study to determine the incidence of phonocardiographically recorded fourth and third heart sounds before and after a double Master's two-step test in patients with angina pectoris due to coronary artery disease and in normal subjects.

Subjects and Methods
One hundred patients with angina pectoris due to coronary artery disease and 100 normal people were subjects. The patients with angina included 98 men and two women, between the ages of 37 and 64 years, with a mean age of 51 ± 6. The normal subjects included 98 men and two women, between the ages of 38 and 64 years, with a mean age of 51 ± 6. The normal subjects were hospital personnel or their friends. All of the normal subjects had blood pressures below 140/90 mm Hg, and none of them were on any medication. Twenty-seven of the patients with angina pectoris had coronary artery disease documented by previous coronary angiography, with 50% or greater narrowing of the lumen of at least one major vessel. The other 73 patients with angina pectoris had a documented transmural myocardial infarction at least 6 months old, with evolution of abnormal Q waves on serial electrocardiograms. None of the patients with angina had A-V block, bundle branch block, valvular heart disease, a myocardiopathy, a high cardiac output state, or a blood pressure above 150/98 mm Hg. None of these patients were on diuretics or digitalis within 3 weeks of this study; none were on quinidine or procainamide within 3 days of this study; none were on antianginal drugs except for nitroglycerin within 3 days of this study; and none were on nitroglycerin on the day of this study.
All 200 subjects had simultaneous electrocardiograms, by lead II, and phonocardiograms recorded in the supine position at the maximum apical impulse at rest and immediately, 2, 4, and 6 min after performing a double Master's two-step test. An eight-channel recorder (Sanborn-Hewlett-Packard-350 series) was used. Phonocardiograms were obtained with a dynamic microphone (Sanborn-Hewlett-Packard), with a frequency response between 25 and 400 Hz. All tracings were recorded at 75 mm/sec with 0.04 sec time lines. In addition, a separate electrocardiogram was simultaneously recorded with an electrocardiograph. This 12-lead electrocardiogram was obtained at rest, and leads II, V2, V4, V5, and V6 were obtained immediately, 2, 4, and 6 min after the double Master's two-step test. All tests were done on an outpatient basis.

A fourth heart sound, illustrated in figure 1, was defined as a low frequency vibration occurring more than 0.07 sec after the onset of the P wave of the simultaneous electrocardiogram but preceding the onset of the QRS complex.2 A third heart sound, illustrated in figure 1, was defined as a low frequency vibration occurring 0.10 to 0.24 sec after the onset of the aortic component of the second heart sound.2

Criteria used for a positive exercise electrocardiogram were the following: ST-segment elevation of either ≥0.5 mm or ≥1.0 mm above the resting level; ST-segment depression of either ≥0.5 mm or ≥1.0 mm below the resting level, with the ST segment extending horizontally for at least 0.08 sec; and ST-segment depression of either ≥0.5 or ≥1.0 mm below the resting level, with downward sloping of the ST segment.

The phonocardiograms and electrocardiograms at rest and after exercise were reviewed by the authors after the study was completed. We did not know whether the tracings under review were from a patient or from a normal subject. The final interpretation was the consensus of the group.

Results

Table 1 indicates the incidence of abnormal exercise electrocardiograms in the patients.
with angina and in the normal subjects. Fifty-nine of the 100 patients (59%) and four of the 100 normal subjects (4%) had an ischemic ST-segment shift $\geq 1.0$ mm. Sixty-seven of the 100 patients (67%) and six of the 100 normal subjects (6%) had an ischemic ST-segment shift $\geq 0.5$ mm.

Table 2 indicates the incidence of fourth and third heart sounds at rest and after exercise in the patients with angina and in the normal subjects. Forty-three of the 100 patients (43%) and 14 of the 100 normal subjects (14%) had a fourth heart sound at rest, and 94 of the 100 patients (94%) and 29 of the 100 normal subjects (29%) had a fourth heart sound after exercise. Fifteen of the 100 patients (15%) and one of the normal subjects (1%) had a third heart sound at rest, and 60 of the 100 patients (60%) and 11 of the 100 normal subjects (11%) had a third heart sound after exercise.

Five of six normal subjects (83%), who had an abnormal exercise electrocardiogram with ischemic ST-segment depression $\geq 0.5$ mm had a fourth heart sound after exercise. Three of 100 patients (3%) and one of 100 normal subjects (1%) had an abnormal exercise electrocardiogram of $\geq 0.5$ mm, but no fourth heart sound after exercise. Table 3 indicates the incidence of either an electrocardiographic response of ischemic ST-segment shift $\geq 0.5$ mm or a fourth heart sound after a double Master's two-step test in the patients with angina and in the normal subjects. Ninety-seven of the 100 patients (97%) and 30 of the 100 normal subjects (30%) had either an ischemic electrocardiographic response of $\geq 0.5$ mm or a fourth heart sound after exercise.

Eighteen of 100 patients (18%) and three of 100 normal subjects (3%) had an abnormal exercise electrocardiogram of $\geq 0.5$ mm, but no third heart sound after exercise. Table 4 indicates the incidence of either an electrocardiographic response of ischemic ST-segment shift $\geq 0.5$ mm or a third heart sound after a double Master's two-step test in the patients with angina and in the normal subjects. Seventy-eight of the 100 patients (78%) and 14 of the 100 normal subjects (14%) had either an ischemic electrocardiographic response of $\geq 0.5$ mm or a third heart sound after exercise.

All of the patients and normal subjects who had a fourth heart sound at rest also had a fourth heart sound after exercise. All of the patients and the normal subject who had a third heart sound at rest also had a fourth heart sound at rest. All of the patients and normal subjects who had a third heart sound after exercise also had a fourth heart sound after exercise.

All of our normal subjects completed the double Master's two-step test without any chest pain developing. Forty-nine of our 100 patients (49%) developed angina pectoris after performing the Master's two-step test. Thirty-three of these patients were unable to complete the test because of angina; five of these patients developed angina at the completion of the test; and 11 of these patients developed angina immediately after lying down.

### Table 1

<table>
<thead>
<tr>
<th>No. of subjects</th>
<th>Degree of ischemic ST-segment shift</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$\geq 0.5$ mm</td>
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<tr>
<td>Anginal patients (100)</td>
<td>67</td>
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<tr>
<td>Normal subjects (100)</td>
<td>6</td>
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</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>No. of subjects</th>
<th>Fourth heart sound</th>
<th>Third heart sound</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rest</td>
<td>After exercise</td>
</tr>
<tr>
<td>Anginal patients (100)</td>
<td>43</td>
<td>94</td>
</tr>
<tr>
<td>Normal subjects (100)</td>
<td>14</td>
<td>29</td>
</tr>
</tbody>
</table>
Thirty-nine of the 49 patients (80%) who developed angina after exercise had an ischemic ST-segment shift ≥0.5 mm. Thirty-six of the 49 patients (73%) who developed angina after exercise had an ischemic ST-segment shift ≥1.0 mm. Forty-nine of the 49 patients (100%) who developed angina after exercise had a fourth heart sound after exercise. Thirty-eight of 49 patients (78%) who developed angina after exercise had a third heart sound after exercise.

**Discussion**

Fifty-nine of our 100 patients (59%) with angina pectoris due to documented coronary artery disease and four of our 100 normal subjects (4%) had an ischemic ST-segment shift ≥1.0 mm, and 67 of our 100 patients (67%) and six of our 100 normal subjects (6%) had an ischemic ST-segment shift ≥0.5 mm after a double Master’s two-step test. Friedberg and his associates reported that 16 of 33 patients (49%) with clinical evidence of angina pectoris had an ischemic ST-segment depression ≥1.0 mm, and that 19 of these 33 patients (55%) had an ischemic ST-segment depression ≥0.5 mm following a double Master’s two-step test. Most and his associates demonstrated that 39 of 65 patients (58%) with angina pectoris due to arteriographically documented coronary artery disease had an ischemic ST-segment depression ≥1.0 mm, and 66% of their 65 patients had an ischemic ST-segment depression ≥0.5 mm following a double Master’s two-step test. Mason and his associates found that 25 of 41 patients (61%) with angina pectoris due to arteriographically documented coronary artery disease and one of 63 normal subjects (2%) had an ischemic ST-segment shift ≥1.0 mm following a double Master’s two-step test.

McGinn and his associates recorded phonocardiograms in 30 patients with old myocardial infarctions, no active angina pectoris, and no fluoroscopic evidence of a ventricular aneurysm, and they demonstrated a fourth heart sound in seven patients (23%) and a third heart sound in four patients (13%). Zoneraich and Zoneraich recorded phonocardiograms in 200 hospitalized patients with coronary artery disease. They reported that 87% of these 200 patients had a fourth heart sound, and 33% of these 200 patients had a third heart sound. Forty-three of our 100 patients (43%) with angina pectoris had a fourth heart sound at rest, and 94% of our patients had a fourth heart sound after exercise.

All of our patients who had a third heart sound after exercise also had a fourth heart sound after exercise. Ninety-seven of our 100 patients (97%) with angina had either an abnormal exercise electrocardiogram with an ischemic ST-segment shift ≥0.5 mm or a fourth heart sound after exercise. Thus, only 3% of our patients with angina pectoris due to documented coronary artery disease did not develop either an ischemic ST-segment shift ≥0.5 mm or a fourth heart sound following a double Master’s two-step test.

Barlow states that the fourth heart sound is associated with ventricular filling resulting from atrial systole, with increased resistance to ventricular filling. Benchimol and Dimond postulate that an ischemic left ventricle has an increased resistance to distensibility, causing the left ventricular end-diastolic pressure to rise, and the left atrium to contract more vigorously. This increased force of atrial

**Table 3**

<table>
<thead>
<tr>
<th>No. of subjects</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anginal patients (100)</td>
<td>97</td>
<td>97</td>
</tr>
<tr>
<td>Normal subjects (100)</td>
<td>30</td>
<td>30</td>
</tr>
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</table>

**Table 4**

<table>
<thead>
<tr>
<th>No. of subjects</th>
<th>No.</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Anginal patients (100)</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>Normal subjects (100)</td>
<td>14</td>
<td>14</td>
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contraction suddenly distending the left ventricle probably produces the vibrations recognized as the fourth heart sound.

However, 14% of our normal subjects, between the ages of 38 and 64 years, had a fourth heart sound at rest, and 29% of our normal subjects had a fourth heart sound after exercise. None of these normal people had systemic hypertension, any valvular disease, a myocardiopathy, or a high cardiac output state, conditions associated with a fourth heart sound. Twenty-four of the 29 normal subjects who had a fourth heart sound after exercise had a normal electrocardiographic response to exercise.

These 29 normal subjects also had a simultaneous phonocardiogram and apexcardiogram at rest and after a double Master's two-step test in a follow-up study. All 14 normal subjects who had had a fourth heart sound at rest again had a fourth heart sound at rest. All 29 normal subjects who had had a fourth heart sound after exercise again had a fourth heart sound after exercise. All fourth heart sounds recorded in this study also coincided with the A wave of the apexcardiogram.10 We are following our normal subjects to determine whether the normal subjects who had a fourth heart sound at rest or after exercise will develop an increased incidence of clinical heart disease.

Acknowledgment

We are indebted to Nicholas Papageorge's, M.D., James Dendinger, B.S., and Richard Heisler, M.D., for referral of patients and technical assistance.

References
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Circulation. 1971;43:273-277
doi: 10.1161/01.CIR.43.2.273
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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