Instant Electrocardiography
Use in Cardiac Exercise Programs

By John D. Cantwell, M.D., and Gerald F. Fletcher, M.D.

SUMMARY
Instant electrocardiograms before and after physical activity were recorded three times per week for three to six months in ten patients with postmyocardial infarction angina pectoris who engaged in a physical training program. Four patients developed ST-segment depressions of over 2 mm following exercise and one of the four had associated ventricular ectopia. Three other patients had asymptomatic runs of ventricular tachycardia. Two of the latter subsequently developed ventricular fibrillation during moderate physical activity and one subsequently died suddenly at home while engaged in yardwork.

Instant electrocardiography represents a simple way to screen for patients prone to exercise-induced arrhythmias. It is felt that the latter should be on antiarrhythmic drugs and be limited to rather light physical activity such as certain flexibility exercises, noncompetitive team sports, and moderately brisk walking.

Additional Indexing Words: Ventricular fibrillation Ventricular tachycardia Physical training program

There are numerous physical training programs for the prevention and treatment of coronary atherosclerotic heart disease in this country1, 2 and in various parts of the world.3-4 The success of this form of therapy is, to a large extent, dependent upon the safety of the environment in which the patient trains. In most programs doctors and nurses record the heart rate and blood pressure at various levels of exercise and have on hand equipment for cardiopulmonary resuscitation. The purpose of this report is to describe an additional safety device that we often employ, namely, the assessment of cardiac rate, rhythm, and repolarization (ST-segment and T wave) responses to exercise through instant electrocardiography.

Materials and Methods
Ten Caucasian male patients (mean age 53 ± 5.4 years) with postmyocardial infarction angina pectoris were chosen for evaluation during their attendance at a medically-supervised gymnasium exercise program held three times weekly at Georgia Baptist Hospital in Atlanta, Georgia. (The number of patients in the study was limited to this group of ten to allow evaluation among patients with similar clinical features.) Three of the patients were receiving long-acting nitrate preparations and one other subject was taking propranolol. Nitroglycerin was readily available and frequently used by the subjects during the exercise periods. None of the patients had clinical evidence initially of refractory arrhythmias, congestive heart failure, ventricular aneurysms, or complicating systemic illnesses.

The technique of obtaining instant electrocardiographic rhythm strips involved use of defibrillator paddles through which an electrocardiographic signal was received. The latter was viewed on a small oscilloscope and simultaneously written out graphically on a recorder. The signal was received from a negative position near (to right or left of) the sternum and a positive position near the cardiac apex (fig. 1). This method of recording is similar to that utilized by CAPRI.*

The sequence of evaluation consisted of obtaining a routine recording of at least 15 cardiac cycles immediately prior to and immediately following the walk-jog sequence of exercise. The tracings were taken within 15 seconds after cessation of activity, and because of the small number of patients, no one was delayed by standing in line. In addition, electrocardiograms were recorded at other times if the patient experienced severe angina pectoris, palpitations, dizziness, vertigo, or other symptoms that were considered unusual.

The supervising physician analyzed the tracings immediately after recording for variations in heart rate and rhythm, conduction disturbances, and ST-segment and T wave changes. This information was later correlated with the 12-lead electrocardiograms, submaximal exercise stress tests — submaximal stress tests (as described elsewhere6) — and clinical events that developed during the period of evaluation, and served as a guide for subsequent therapy.

Results
Data acquired in the evaluation, along with other clinical information on the patients and individual program modification resulting from this evaluation,

*CAPRI — Cardiopulmonary Rehabilitation Institute, Seattle, Washington.
Technique of obtaining instant electrocardiographic rhythm strips with the defibrillator paddle electrodes, oscilloscope, and graphic recorder.

are seen in table 1. In four of ten patients, exercise produced a significant ST-segment depression. The ST-segment depression was often seen in the absence of chest pain. One patient had couplets of premature ventricular complexes in conjunction with the ST-segment depression (fig. 2). Two additional patients had brief paroxysms of asymptomatic ventricular ectopy following exercise. Two separate episodes were recorded in the same individual (fig. 3).

Two other patients developed ventricular fibrillation. The first was a 57-year-old man who had been in the exercise program for two uneventful years and had had a single episode of exercise-related ventricular tachycardia (fig. 4). He had previously tolerated heart rates of up to 150 beats per minute without chest pain or arrhythmias other than an occasional ventricular premature beat. His exercise prescription was reduced and during the next three months he had no arrhythmias. However, during a subsequent exercise session, he collapsed after alternately walking and slowly jogging for one mile. Ventricular fibrillation was recorded on an instant rhythm strip and he was successfully resuscitated. The patient has subsequently returned to the program and has done well for six months.

The second patient was a 52-year-old patient who had been in the program for 18 months. He had undergone six treadmill stress tests at three-month intervals, tolerating a treadmill test time of 18 minutes and a heart rate of 150 beats per minute without developing signs or symptoms of ischemia. Instant electrocardiography detected one episode of ventricular irritability (fig. 5) after jogging 1,200 yards. During the seventh treadmill stress test after 8½ minutes of exercise, the subject had a ventricular premature complex during the vulnerable period and experienced ventricular tachycardia, followed by ventricular fibrillation (fig. 6). He was promptly defibrillated and released with a prescription for antiarrhythmic agents. He, too, returned to the exercise program, after having been placed on procaine amide, and tolerated brisk walking and flexibility exercises without further incident. However, three months later, while engaged
**Table 1**

*Clinical Data on Ten Patients Evaluated with Instant Electrocardiography*

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (yr)</th>
<th>Period of training (mo)</th>
<th>Period since last coronary event (mo)</th>
<th>Medications other than TNG</th>
<th>Resting ECG</th>
<th>Exercise ECG during study period</th>
<th>Instant ECG &amp; symptoms</th>
<th>Program modification &amp; results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>47</td>
<td>16</td>
<td>30</td>
<td>Isosorbide dinitrate</td>
<td>Old IMI</td>
<td>HR = 75-120</td>
<td>HR = 70-150</td>
<td>Ex Rx: reduced to lower HR endpoint</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clofibrate</td>
<td></td>
<td>Negative</td>
<td>NS ST &amp; T</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>44</td>
<td>12</td>
<td>24</td>
<td>None</td>
<td>Old IMI</td>
<td>HR = 60-130</td>
<td>HR = 60-150</td>
<td>Ex Rx: reduced to lower HR endpoint</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Negative</td>
<td>NS ST &amp; T</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>57</td>
<td>16</td>
<td>24</td>
<td>Warfarin sodium</td>
<td>Old IMI</td>
<td>HR = 90-140</td>
<td>HR = 70-140</td>
<td>No change except TNG prior to walk-jog</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clofibrate</td>
<td></td>
<td>Positive</td>
<td>NS ST &amp; T changes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Oec PVC &amp; AP with HR = 140</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>53</td>
<td>2</td>
<td>7</td>
<td>Digoxin</td>
<td>Old IMI</td>
<td>HR = 80-115</td>
<td>HR = 80-140</td>
<td>Ex Rx: reduced, quinidine increased</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Quinidine</td>
<td>&amp; ASMI</td>
<td>False positive</td>
<td>PVCs in couplets with</td>
<td>PVC couplets resolved</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Frequent PVCs</td>
<td>“palpitations”</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Positive ST changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rare AP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>59</td>
<td>9</td>
<td>15</td>
<td>Hydrochlorothiazide</td>
<td>Old IMI</td>
<td>HR = 60-100</td>
<td>HR = 60-120</td>
<td>No change NTG urged</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Spironolactone</td>
<td></td>
<td>Positive</td>
<td>NS ST changes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Few PVCs</td>
<td>Mild AP with ST changes</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>47</td>
<td>11</td>
<td>15</td>
<td>Warfarin sodium</td>
<td>Old ALMI</td>
<td>HR = 75-160</td>
<td>HR = 50-150, NS ST &amp; T changes</td>
<td>Ex Rx: reduced slightly NTG urged</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
<td>Oec AP in gym</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>60</td>
<td>9</td>
<td>15</td>
<td>Clofibrate</td>
<td>Old IMI</td>
<td>HR = 70-130</td>
<td>HR = 75-140</td>
<td>Ex Rx: reduced, AP persisted with stated drugs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Isosorbide dinitrate</td>
<td></td>
<td>Positive</td>
<td>positive S-T changes</td>
<td>had surgical coronary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>with HR = 120</td>
<td>with HR = 120</td>
<td>revascularization with good</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
<td></td>
<td>results and returned to program</td>
</tr>
</tbody>
</table>
Cardiac complications during exercise training have been reported in coronary-prone individuals and in postmyocardial infarction patients. Bruce and Kluge recently described seven instances of exertional cardiac arrest in coronary patients, five occurring during exercise testing and two during exercise training. All patients responded to a single shock from a defibrillator. Bruce referred to a single additional similar event. Friedman et al. described clinical and pathological findings in persons who died suddenly (prior to or within 30 seconds after the onset of signs or symptoms) and in those suddenly (i.e., minutes to 24 hours after the onset of signs or symptoms). Of 27 patients suddenly died suddenly at home while engaged in yardwork.

*Had episode of ventricular tachycardia and fibrillation during exercise testing with successful resuscitation; returned to the exercise program but subsequently died suddenly at home while engaged in yardwork.

†Had episode of ventricular fibrillation in gym with successful resuscitation and subsequently returned to exercise program.

Discussion

Cardiac complications during exercise training have been reported in coronary-prone individuals and in postmyocardial infarction patients. Bruce and Kluge recently described seven instances of exertional cardiac arrest in coronary patients, five occurring during exercise testing and two during exercise training. All patients responded to a single shock from a defibrillator. Bruce referred to a single additional similar event. Friedman et al. described clinical and pathological findings in persons who died suddenly (prior to or within 30 seconds after the onset of signs or symptoms) and in those suddenly (i.e., minutes to 24 hours after the onset of signs or symptoms). Of 27

**Figure 4**

Paroxysmal asymptomatic ventricular tachycardia following talk.

**Figure 5**

Three consecutive ventricular premature beats, initiated by a fusion beat, in a 53-year-old man immediately after jogging 1,200 yards.

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<table>
<thead>
<tr>
<th>HR = 75-150</th>
<th>HR = 70-150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old IMI</td>
<td>Old AMI</td>
</tr>
<tr>
<td>False positive</td>
<td>Positive</td>
</tr>
<tr>
<td>NS ST &amp; T changes, PVCs (3-in-a-row)</td>
<td>Positive ST changes, Occ PVC &amp; AP</td>
</tr>
</tbody>
</table>

Ex Rx: markedly reduced after VF

Placed on procaine amide

Ex Rx: reduced with results of less PVCs and AP

Abbreviations: TNG = nitroglycerin; Ex Rx = exercise prescription; ECG = electrocardiogram; HR = heart rate in beats/min; NS ST & T = nonspecific ST and T changes; IMI = inferior myocardial infarction; ASMI = anterior-superior myocardial infarction; ALMI = anterolateral myocardial infarction; AMI = anterior myocardial infarction; Positive = positive ST-segment changes suggestive of ischemic heart disease; Negative = no ST-segment changes; AP = angina pectoris; VT = ventricular tachycardia; PVC = premature ventricular contraction; False Positive = significant ST changes but patient on digitalis; Occ = occasional.

8* 52 13 22

Propranolol
Digoxin
Warfarin sodium

Old IMI

HR = 75-150
False positive

NS ST & T changes, PVCs (3-in-a-row)
AP

Ex Rx: markedly reduced after VF

Placed on procaine amide

Ex Rx: reduced with results of less PVCs and AP

Abbreviations: TNG = nitroglycerin; Ex Rx = exercise prescription; ECG = electrocardiogram; HR = heart rate in beats/min; NS ST & T = nonspecific ST and T changes; IMI = inferior myocardial infarction; ASMI = anterior-superior myocardial infarction; ALMI = anterolateral myocardial infarction; AMI = anterior myocardial infarction; Positive = positive ST-segment changes suggestive of ischemic heart disease; Negative = no ST-segment changes; AP = angina pectoris; VT = ventricular tachycardia; PVC = premature ventricular contraction; False Positive = significant ST changes but patient on digitalis; Occ = occasional.

9† 57 24 30

Digoxin
Warfarin sodium
Isosorbide dinitrate

Old ASMI

HR = 75-150
False positive
Few PVCs

HR = 60-140
Positive ST with occ PVCs and AP
One run of VT

Ex Rx: reduced with results of less PVCs and AP

Abbreviations: TNG = nitroglycerin; Ex Rx = exercise prescription; ECG = electrocardiogram; HR = heart rate in beats/min; NS ST & T = nonspecific ST and T changes; IMI = inferior myocardial infarction; ASMI = anterior-superior myocardial infarction; ALMI = anterolateral myocardial infarction; AMI = anterior myocardial infarction; Positive = positive ST-segment changes suggestive of ischemic heart disease; Negative = no ST-segment changes; AP = angina pectoris; VT = ventricular tachycardia; PVC = premature ventricular contraction; False Positive = significant ST changes but patient on digitalis; Occ = occasional.

10 49 12 21

None

Old AMI

HR = 70-120
Positive

HR = 60-140
Positive ST changes
Occ PVC & AP

No change

Abbreviations: TNG = nitroglycerin; Ex Rx = exercise prescription; ECG = electrocardiogram; HR = heart rate in beats/min; NS ST & T = nonspecific ST and T changes; IMI = inferior myocardial infarction; ASMI = anterior-superior myocardial infarction; ALMI = anterolateral myocardial infarction; AMI = anterior myocardial infarction; Positive = positive ST-segment changes suggestive of ischemic heart disease; Negative = no ST-segment changes; AP = angina pectoris; VT = ventricular tachycardia; PVC = premature ventricular contraction; False Positive = significant ST changes but patient on digitalis; Occ = occasional.
instantaneous deaths, more than half occurred during or immediately after moderate to severe physical activity. Autopsy studies in the latter group generally revealed extensive coronary atherosclerosis in the absence of an acute myocardial infarction, suggesting cardiac electrical dysfunction as the mechanism of death. Of seven subjects with identified ventricular fibrillation in this group, none could be revived. Bruce\textsuperscript{10} has suggested that excessive delay and/or questionable techniques in resuscitation measures may explain the discrepancy between these failures and his successes.

In any event, since life-threatening arrhythmias do occasionally occur in conjunction with exercise, means of detecting the arrhythmia-prone persons in advance must be considered. In our experience, instant electrocardiography has complemented exercise stress testing and other screening measures in such detection. Two of our four patients with asymptomatic exercise-related ventricular arrhythmias (which would have gone undetected without the instant electrocardiogram) subsequently developed ventricular fibrillation during walk-jog activity and during exercise stress testing. In retrospect, moderate exercise such as walking should probably have been prescribed after the first detection of ventricular ectopy.

One could also argue that such persons should be omitted from the training program altogether. Since both our patients had derived considerable subjective benefits from the program and were desirous of returning to even a limited portion of the sessions, we have allowed them to do so, feeling that they were safer in the supervised gymnasium program than in any situation short of a coronary care unit.

While instant electrocardiograms certainly appear useful, one might obtain additional information by using continuous radio-telemetry monitoring during all phases of exercise. We have done this on several occasions and have noted repolarization changes during various phases of exercise; however, equipment cost and lack of personnel prevent widespread application of this technique.

References
5. Fletcher GF, Cantwell JD: Exercise in the Management of Coronary Heart Disease. Springfield, Ill, Charles C Thomas, 1971
7. Cantwell JD, Fletcher GF: Cardiac complications while jogging. JAMA 210: 101, 1969

Figure 6
Ventricular tachycardia during exercise stress testing in the patient described in figure 5.
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