Exercise Techniques for Radionuclide Angiocardiography

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Evaluation of cardiac function during stress exercise provides important information unavailable from studies performed at rest. Adequate data are difficult to obtain during exercise because of the brief duration of the cardiac cycle, the rapid transit of tracer through the heart, and patient motion during exercise. During rest and exercise, we performed radionuclide angiocardiograms in the erect position on normal subjects and patients with coronary artery disease (CAD). The electrocardiogram (ECG) was telemetered and the blood pressure was monitored at regular intervals. A prior treadmill exercise test in all subjects with CAD had documented the heart rate-blood pressure (HR-BP) product at which ischemic myocardial changes occurred on ECG. A bicycle ergometer provided a gradually increasing work load from 200 kilopond meters/min to 700 kpm/min to achieve 80% of the maximal HR-BP product achieved during treadmill testing. Cardiac chamber wall motion and volume changes during individual cardiac contractions were assessed at heart rates greater than 200 beats/min. When properly performed, resting and exercise initial transit radionuclide angiocardiograms provide a large amount of important hemodynamic information with little patient risk or discomfort.

Heart disease is the most prevalent health problem in the United States today. Resting radionuclide angiocardiograms provide clinically useful information in patients with cardiac disorders (*1*). These studies may also be performed during exercise, and evaluation of cardiac function during the stress of exercise provides a sensitive indicator of functional cardiac reserve. We describe our technique for performing radionuclide angiocardiography, emphasizing the unique aspects of the study that have been introduced by exercise.

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Since exercise commonly induces cardiac rhythm disturbances in patients with cardiac disease, attention to *patient safety* is of utmost importance (*2*). The second unique consideration imposed by exercise is that the rapid heart rate and brief duration of each cardiac contraction limit the statistical *accuracy of data* acquired. Therefore, a highly sensitive gamma camera is essential for performing these studies from the first transit of tracer through the heart (*3*). Also, body motion associated with exercise must be minimized. The stress exercise imposed should be similar to that commonly encountered in daily activity and should *physiologically stress* the cardiorespiratory system, rather than fatigue isolated muscle groups (*4, 5*). The fourth objective is *efficiency,* so that the study may be performed with patient comfort and convenience. Data acquisiton and processing should be sufficiently simple to permit practical application of the study to routine clinical practice (*6*).

Methods

In preparation for the study, the technologist becomes familiar with the patient's clinical history, particularly noting any previous episodes of significant arrhythmias or cardiopulmonary arrest. The patient is informed of the plan of study to relieve anxiety and ensure cooperation during exercise. The patient is then placed supine and ECG leads are applied to the chest in the orientation corresponding to the V-lead with the QRS complex of greatest magnitude. Telemetry of the ECG signal avoids encumbrances associated with wires attached to the patient. A blood pressure cuff is then applied for subsequent monitoring of systemic pressure; resting pulse and blood pressure are recorded.

The external jugular vein is an excellent injection site because of ease of needle insertion, patient acceptance, and the discrete tracer bolus that commonly results (Fig. 1A). A 1¼-in., 20-gauge indwelling Teflon® catheter is inserted, which allows the patient freedom of

FIG. 1. (A) Indwelling catheter placed in an external jugular vein with (B) attached three-way stopcock, i.v. tubing, 20-ml syringe, saline flush provides a discrete tracer bolus.

movement during exercise without risk of infiltration. To insure a discrete injection, an assembled stopcock, intravenous tubing, and 20-cc syringe filled with saline are attached to the catheter (Fig. 1B). At the time of injection a 15-mCi bolus of Tc-99m pertechnetate is introduced through the stopcock into the tubing and injected through the needle by brisk emptying of the syringe. Data are recorded over the precordium at 50-msec intervals during the initial passage of the tracer.

The patient is placed in the erect position on a bicycle ergometer (Fig. 2). A straight anterior view of the chest is obtained by aligning the chest midline 2 cm to the right of the center of the collimator. The field of view must extend superior to the sternal notch and inferior to the xiphoid. A transmission image of the cardiac silhouette produced from a Co-57 flood source may be used to document accurate patient positioning. Exercise is then begun with a 200-kpm/min resistance on the bicycle ergometer. A kilopond (kp) is defined as the force required to accelerate 1 kg to 1 m/sec^2. This measurement obtained in addition to the mileage traversed during the study permits a measurement of work that can be related to oxygen consumption for physiologic studies.

The resistance is increased at a rate of 100 kpm/min to a maximum work load, which does not exceed 700 kpm/min. The patient is advised to request less resistance as muscle fatigue is noted so that general body fatigue occurs before fatigue of the legs. The ECG is monitored continuously during exercise and recovery and may be used to obtain pulse rates. Blood pressures are obtained at 2-min intervals during exercise. Measurement of pulse and blood pressure documents the physiologic response to exercise and is important for safe performance of the study.

The systemic blood pressure may increase during exercise in normal subjects (Fig. 3). Patients with myocardial ischemia may have decreased blood pressure such as occurred in the patient illustrated (Fig. 3) indicating the need to immediately inject and complete the study.

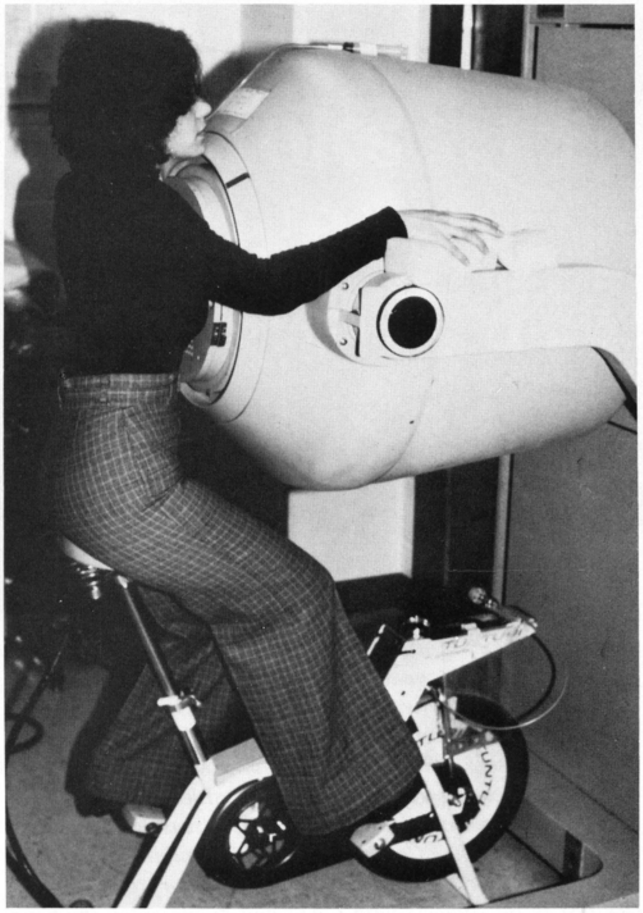

FIG. 2. Exercise performed on the bicycle ergometer is similar to that encountered in daily activities. The erect position allows data accumulation while maintaining the desired heart rate.

The single consideration of greatest importance in patient safety is continuous monitoring of the ECG (Fig. 4). The electrocardiographic change most typical of ischemia is depression of the ST segment of the tracing. The premature ventricular contraction (PVC) indicating irritability of the ventricle is recognized by the broad QRS complex commonly followed by a pause. The appearance of PVCs during exercise becomes particularly ominous when it occurs during consecutive cardiac contractions. When more than five PVCs occur sequentially, the condition is termed ventricular tachycardia; this must be considered an emergency since this unstable condition commonly deteriorates to frank ventricular fibrillation. Ventricular fibrillation is an erratic ECG signal without a characteristic pattern; it requires immediate cardiopulmonary resuscitation.

Results and Discussion

While constant attention must be paid to patient safe-

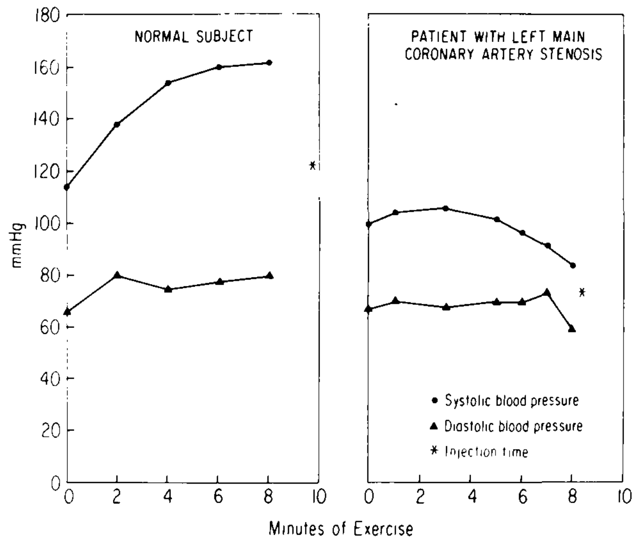

FIG. 3. Blood pressure readings indicate the patient's response to exercise. Note that injection was completed when systolic pressure dropped in the patient with CAD.

ty, this procedure is not unduly hazardous since less stress exercise must be induced than is commonly used for a treadmill determination. During the past year we have performed 1,000 exercise radionuclide angiocardiograms at Duke University Medical Center without a single complication. Nevertheless, the potential for sudden emergencies in all patients with cardiac disease becomes more pronounced in the study of patients during and after stress exercise.

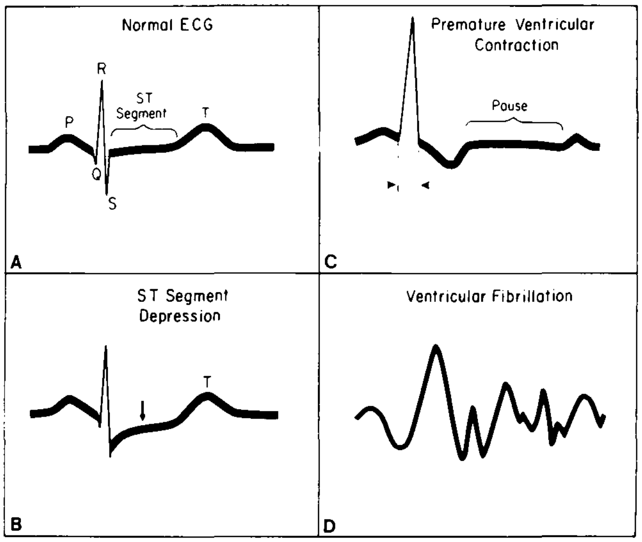

FIG. 4. Stylized ECG tracings represent conditions possibly encountered during stress exercise. Major points along normal tracing (A) are identified by letters. Patients with cardiac disease may appear normal at rest, but show symptoms of cardiac muscle ischemia (B) or impaired conduction of electrical impulses (C) when exercising. Ventricular fibrillation indicates that cardiopulmonary resuscitation should be started immediately.

The purpose of exercise is to induce a maximum cardiac output. Important information, however, may be obtained at submaximal exercise, and there is no need to press the patient beyond well-defined endpoints of exercise. The appearance of the previously mentioned electrocardiographic changes, which represent warning signs of myocardial ischemia and irritability, represent valid endpoints of exercise. A significant decrease in blood pressure is another important endpoint. Following the onset of significant angina, injection should be made and the study completed. In patients who continue exercise without angina or blood pressure or ECG alterations, an endpoint of 80% of the maximal heart rate-blood pressure product, as predicted by a prior treadmill exercise test, has been found to serve as a valid level of stress.

The normal response to exercise is little change in the end diastolic volume and an increase in ejection fraction in comparison to the resting state. During exercise, patients with myocardial ischemia increase the end diastolic and end systolic heart volume and may actually decrease left ventricular ejection fraction (*7*). Patients with minimal CAD increase ejection fraction to a subnormal level.

In summary, the protocol described, which induces physiologic stress by exercise, can be conveniently and safely performed on patients through careful attention to technical details. The resulting information about blood flow and cardiac function aids in the management of patients with heart disease.

Acknowledgment

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