Assessment of left ventricular function during upright treadmill exercise with tantalum 178 and multiwire gamma camera

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Background. **Prior studies with first-pass radionuclide angiography (RNA) during treadmill exercise used a single-crystal (Anger) or multicrystal gamma camera and technetium 99m tracers. Motion correction, when done, used point sources, which limited correction to only plane movement.**

Methods and Results. **We examined the performance of a multiwire gamma camera (MWGC), generator-produced tantalum 178, and a novel method of motion correction during treadmill exercise testing. We studied 100 patients in whom rest and stress gated tomographic myocardial perfusion images were obtained. Eight patients were excluded because of incomplete data. There were 53 men and 39 women aged 52 ± 12 years. The resting left ventricular (LV) ejection fraction (EF) was 61% ± 12% by gated single photon emission computed tomography. Stress myocardial perfusion was normal in 83 patients and abnormal in 9 patients. The resting RNA EF in the upright position was 57% ± 12% (r = 0.52, P = .0001 vs gated EF). At peak exercise, the EF by MWGC was 60% ± 26% if uncorrected and 69% ± 13% after motion correction. Among the 80 patients with normal perfusion and normal resting EF by gated single photon emission computed tomography, a normal response to exercise was seen in 52 (63%) without motion correction and 74 (89%) with motion correction (P < .05).**

Conclusion. **Assessment of LV function is feasible with MWGC. The motion-corrected images significantly improved the results. (J Nucl Cardiol 2005;12:560-6.)**

Key Words: Left ventricular function • tantalum 178 • multiwire gamma camera • radionuclide angiography

Assessment of left ventricular (LV) function during exercise is useful in the detection and risk assessment of patients with coronary artery disease (CAD). Patients with an exercise LV ejection fraction (EF) of 60% or greater have an excellent prognosis with an annual event rate comparable to an age-matched normal population.[1-7] Most of these studies were performed with either first-pass or gated radionuclide angiography (RNA). First-pass RNA is challenging because of motion artifacts during exercise. Previous studies used an external point source for correcting cardiac motion.[8-10] The point source is typically 10 to 15 mCi americium 241 attached to the anterior chest wall. This technique limits the correction to only a single plane and assumes that the patient is rotationally fixed. In addition, in these previous studies technetium 99m was used as the tracer, which has an ideal energy level (140 keV) but a relatively long half-life of 6 hours and hence a relatively high radiation burden if multiple studies are done. Tantalum 178 is a generator-produced radiotracer that has a short half-life of 9.3 minutes and a low energy (55-65 keV), resulting in a low radiation exposure that makes it ideal for serial imaging.[11-13] A specially designed multiwire gamma camera (MWGC) is used for image acquisition and processing. This camera technology has been described previously.[14-17] In summary, the MWGC is a proportional counter detector, which consists of a pressurized gas chamber and 3 parallel wire planes. Ionization by radiation event is collected at the anode, where the charge is amplified by gas avalanches. Outer cathode lines are orthogonally positioned and attached to discrete delay-line grids. The position signal is obtained by measuring the time of delay between the occurrence and arrival of the event by use of high-speed

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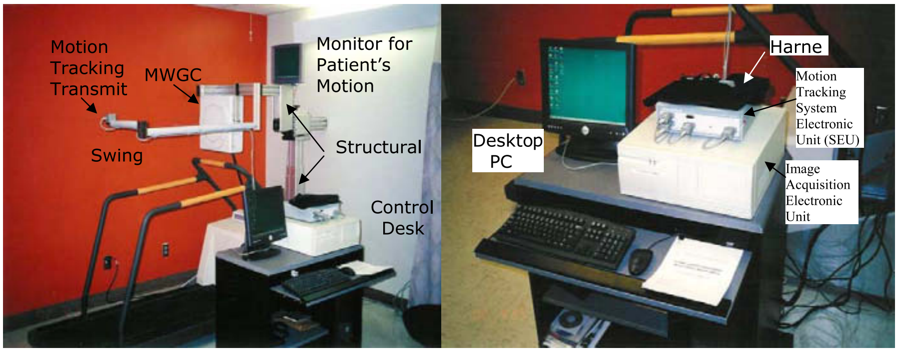

Figure 1. Setup of MWGC, motion-tracking device, and treadmill at the University of Alabama at Birmingham. The *left panel* shows the treadmill unit with the head of the MWGC attached to it. The motion-tracking transmitter is attached to a swinging arm. The monitor on top displays the position of the heart. The *right panel* shows two electronic units, one for motion tracking and the other for image acquisition.

delay-line readout system (mean clearance time, 150 nanoseconds). This enables digital recordings at very high rates (>1 million counts per second) and good image uniformity (±5%). The field of view of the MWGC is 25 cm in diameter. The intrinsic spatial resolution measured as full width at half maximum is 2.5 mm, and the system resolution at the camera surface is 6.9 mm with a high-sensitivity parallel-hole collimator.

The purposes of this study were to examine the feasibility of performing upright rest and peak exercise first-pass RNA and to examine the impact of a novel motion-correction algorithm on the EF responses to exercise in comparison to the results of single photon emission computed tomography (SPECT) perfusion imaging.

MATERIALS AND METHODS

Study Patients

We prospectively studied 100 patients who were referred for exercise SPECT perfusion imaging for clinical reasons. Each patient signed a consent form approved by the Institutional Review Board of the University of Alabama at Birmingham, Birmingham, Ala. Eight patients were excluded because of incomplete RNA data. There were 53 men and 39 women aged 52 ± 12 years. All patients underwent first-pass RNA at rest in the upright position. The patients then underwent symptom-limited treadmill exercise testing. Electrocardiography, blood pressure, and any symptoms were recorded throughout the exercise and recovery periods. Exercise was terminated as a result of excessive fatigue, marked ST changes, hypotension, syncope, severe angina, or severe arrhythmias. Just before peak exercise, repeat first-pass RNA was performed. The MWGC setup is shown in Figure 1. The rest and exercise studies were each obtained with a bolus injection of 15 to 40 mCi Ta-178 in the antecubital vein. Raw nuclear data at 120 frames per second and position data from the motion-tracking sensor were stored in the computer that is integrated in the camera system. After injection of Ta-178, all patients, while exercising at peak exercise, were also injected with Tc-99m tetrofosmin for SPECT imaging and were asked to continue to exercise for 1 additional minute. The exercise RNA data were therefore obtained an average of 2 minutes before the termination of exercise.

Motion-Correction Algorithm

An electromagnetic position/orientation-tracking system (Polhemus Inc, Colchester, Vt) was used for motion correction and consists of a transmitter and a sensor. Excitation of the transmitter results in a sensor output that consists of 6–degree-of-freedom position information including joint-axial rotation. The motion-tracking system and motion-correction algorithm were tested with phantom studies simulating the conditions of treadmill RNA, and errors in position determination were less than the Nyquist spatial sampling rate (hence no image aliasing).[18] Figure 2 shows the setup of the motion-tracking system, which keeps track of cardiac motion used in this study. Patients were asked to wear a special harness with a fixed motion-tracking sensor. The motion-tracking transmitter is attached to a swinging arm of the treadmill behind the patient's back. Before exercise, the chest contour of the patient is marked by use of another mobile sensor at 4 points in the same horizontal plane (8 cm below the sternal angle): the front, back, left, and right sides. This mobile sensor is used only at rest to determine the location of the heart, which is fed into the computer system, and the cardiac location is determined in relation to the fixed sensor attached to the harness (Figure 2). On the basis of the heart location in relation to the sensor (the motion-tracking sensor attached on the harness) and the instantaneous position of the sensor in the transmitter coordinates during exercise, the real-time heart location can be accurately tracked during the patient's movement on the treadmill.[18]

Special software was developed for real-time graphic display of the patient's heart position relative to the camera's field of view during the entire exercise period. Oftentimes, vigorous treadmill exercise can result in a loss of data because