Use of Exercise Gated Blood Pool Scans for Evaluation of Ventricular Function in Aortic Valvular Disease

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Sequential rest-exercise gated blood pool scans were performed to evaluate left ventricular function in seven patients with aortic regurgitation (four males and three females, mean age 38±16), to evaluate the use of this test to provide information helpful in determination of therapy. Exercise was performed with a bicycle ergometer to symptom-limited maximum. Ejection fraction (EF), regurgitant fraction, and pulmonary blood volume were determined on two occasions for each patient (4–16 months apart). Mean rest and exercise EF did not change significantly with time. Group mean regurgitant fraction did not change significantly, whereas pulmonary blood volume increased significantly. However, three patients had a decrease in rest EF on study two, diminished left ventricular reserve function determined by a decrease in EF on exercise, and an increase in pulmonary blood volume on study two without a significant change in exercise regurgitant fraction on the second gated blood pool study, and were recommended to have a cardiac catheterization even though they were relatively asymptomatic. These patients were found to have significant aortic regurtitation and had subsequent aortic valve replacement. In conclusion, patients with aortic valvular disease can be followed with routine rest and exercise gated blood pool scans to determine pathophysiological changes that result from the volume overload; these parameters can be used as a guide to type of therapeutic intervention.

Radionuclide blood pool imaging offers a noninvasive means of assessing left ventricular function at rest and during maximum exercise (*1*). Three parameters which can be used to determine the severity of ventricular dysfunction associated with aortic valvular disease are ejection fraction (EF), regurgitant fraction (RF), and pulmonary blood volume (PBV). In this study, patients with aortic regurgitation were followed sequentially with rest-exercise gated blood pool scans (GBPS) to provide information concerning changes in ventricular function during the progression of disease, and thus, were used in part to determine the choice of long-term therapy.

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Materials and Methods

Patient Population

Sequential rest-exercise GBPS were performed to evaluate left ventricular (LV) function in seven patients with aortic regurgitation (AR) with a mean age of 38 ± 16 years. This group consisted of four males and three females. Ejection fraction (EF), regurgitant fraction (RF), and pulmonary blood volume (PBV) were determined on two occasions for each patient (4–16 months apart).

Scintigraphic Angiography

Each patient undergoing GBPS was injected with cold stannous pyrophosphate (Techne-Scan PYP, Mallinckrodt, Inc., St. Louis, MO) using in-vivo tagging techniques (*2*). Twenty to 30 minutes were allowed for adequate binding of the PYP to the patient's red blood cells. During this time, electrodes were placed on the patient's chest for ECG gating of the computer. The patient was placed in a supine position under a scintillation camera with a low energy, all purpose parallel hole collimator. The camera is interfaced to a dedicated computer (Medtronic Data Systems, Ann Arbor, MI). Twenty mCi [^{99m}Tc] pertechnetate were delivered to the patient via a three-way stopcock, 20–30 minutes after the injection of cold PYP. Ten minutes after tracer injection, supine multigated blood pool images were collected at rest in the anterior, left anterior oblique (LAO 45), and left posterior oblique (LPO 30) projections. Resting gated data were collected in a 64 × 64 byte mode, into 28 frames.

For exercise, the patient was placed on a bicycle ergometer in a 45° semi-erect position in relation to the camera. The camera collimator was placed in the LAO 45 position and approximately 30–40° caudad to facilitate data collection during bicycle exercise. Cardiac monitoring during exercise was done with a 12 lead ECG. A resting LAO 45 semi-erect view was obtained using 64 × 64 byte mode and 14 frames. During this acquisition, baseline ECG and blood pressure were taken. The patient was also asked to hyperventilate for 15 seconds to simulate breathing artifact and an ECG strip was recorded prior to exercise.

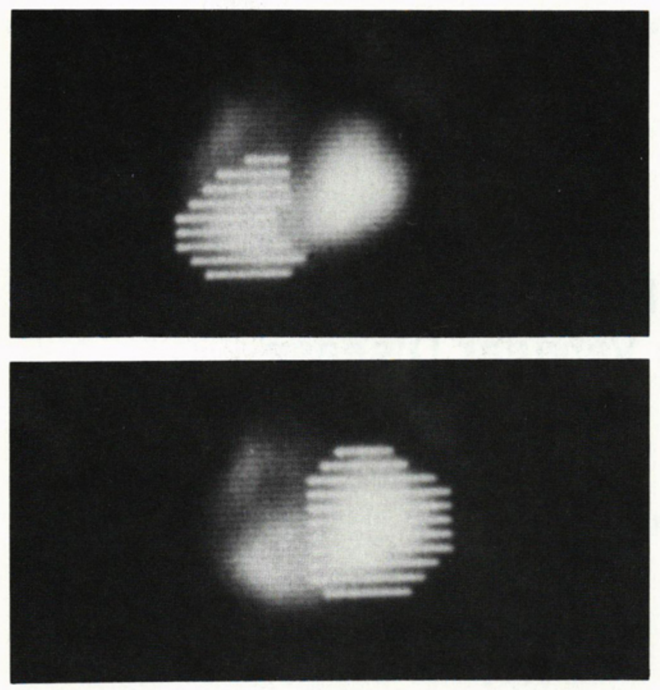

FIG. 1. Example of right ventricle (RV) and left ventricle (LV) stroke volume images. Regions of interest (ROI) are placed on the RV and LV on the amplitude image.

The computer was set up for at least four stages of acquisition at exercise. With a cardiologist present, the patient was then exercised. Each stage of exercise was five minutes in duration to obtain sufficient count activity for evaluation of ventricular function. Each exercise stage became progressively more difficult, by increasing the workload in 25 watts stages (from 25 watts to 100 watts). Each patient was exercised to symptom limited maximum (fatigue, shortness of breath, chest pain, ECG ischemia, or arrhythmias). Immediate post-exercise and ten minute post-exercise images were taken to complete the study.

Ejection Fraction

EFs were determined from resting and maximum exercise LAO 45 semi-erect views for each patient from both sets of studies. A semi-automated edge detection algorithm MUGA (Medical Data Systems, Ann Arbor, MI), based on threshold and second derivative methods, was used to generate a ventricular outline and follow count activity changes throughout the cardiac cycle (*3*). The EF was calculated as follows:

$$EF\ (\%) = \frac{(EDC - BKG) - (ESC - BKG)}{(EDC - BKG)} \times 100$$

where EDC = end diastolic counts, ESC = end systolic counts, and BKG = background.

Regurgitant Fraction

The LAO 45 semi-erect rest and maximum exericise images were filtered using a 5 point spatial filter and a 3 point temporal filter. Phase analysis was performed on filtered images with a Fourier transform program available on the computer. Fourier analysis of time activity curves of individual pixels were used (*4*). This technique allowed the production of three different images for each LAO 45 view. The first is an average image, which represents the sum of all images in the series divided by the total number of images (*5*). The second image, the amplitude image or stroke volume (ED minus ES) image, defines the change in count activity from end diastole to end systole, and is a collective picture of the stroke volume of individual pixels (*5*). The final image, the phase image, is a temporal map of the sequence of cardiovascular emptying (*5*).

The stroke volume image was used to determine right ventricular (RV) and left ventricular (LV) stroke volumes in the following manner: Regions of interest (ROI) were placed using the semi-automated program over RV and LV stroke volume images obtained from rest and maximum exercise LAO 45 gated images (Fig. 1). Count activity in each ventricle was used to represent change in counts during myocardial contraction (stroke volume). LV/RV stroke volume ratios were then calculated and used to determine regurgitant fraction. In normals, the ratio LV/RV stroke volume is close to 1.0 (*6,7*).

Pulmonary Blood Volume

Computer generated ROIs were placed over the right lung apex and base in the end diastolic LAO 45 semi-erect rest and maximum exercise images (*1*) for all patient studies, being careful not to include vascular structures (Fig. 2). Previous investigation indicates that apex/base ratios are less than 1.0 in normals (*8*).

Statistical Analysis

Paired t-tests were applied to the EF, RF, and PBV data comparing resting and maximum exercise data at time one and time two, and also comparing data obtained at time one to that obtained at time two. The results are presented as the mean ± standard deviation (SD).

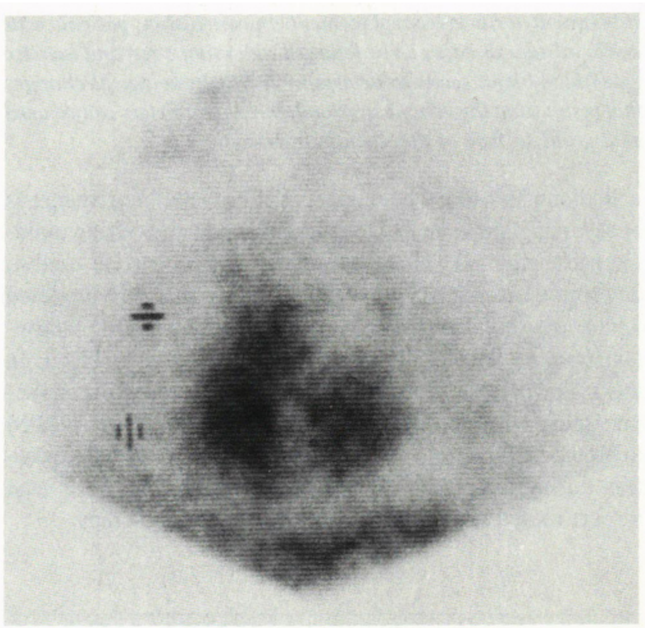

FIG 2. Example of pulmonary blood volume determination. Regions of interest (ROI) are placed on the apex and base of the right lung in end diastole.

TABLE 1. Ventricular Function Parameters (N=7)
(Each value is a mean ± SD)

	Time 1		Time 2	
	Rest	Max Ex	Rest	Max Ex
Ejection Fraction	58 ±12	61 ±9	55 ±4	58 ±8
Regurgitant Fraction	4.6± 4	3.6±4	5.1±4	5.3±7
Pulmonary Blood Volume	0.8± 0.2	1.1±0.3	1.1±0.2*	1.2±4

* $p<.05$ rest 1 versus rest 2

Results

In the total group, the mean rest and exercise EFs and RFs did not change significantly with time (Table 1). The resting PBV increased significantly, from time one to time two, while exercise PBVs were similar at both times.

Patients 1, 2, and 7 (Fig. 3) were found to have decreased LV reserve function at time two, as evidenced by a fall in ejection fraction at maximum exercise. Patients 1 and 7 also had a decrease in resting LVEF at study two compared to the first study. These same patients also had a depressed RF response to exercise, i.e., RF did not fall with exercise at study two as it did in the first study. Rest PBV response increased in all three patients on the follow up study. Exercise PBV response fell slightly in patient 2, but did not change for patients 1 and 7, presumably because the PBV could not increase from the already increased resting level.

Conclusion

In conclusion, patients with AVD can be followed with routine R-E gated blood pool scans to determine pathophysiological changes which result from the volume overloads. These parameters can be used as a guide to type of therapeutic intervention. The best example of how these parameters can be used were demonstrated in patients 1, 2, and 7. These patients were relatively asymptomatic and were being studied at routine six month checkups. Because of their abnormal response to exercise (decrease in ejection fraction at maximum exercise) at time two, and because of abnormal regurgitant fraction and pulmonary blood volume values, it was recommended that these patients have cardiac catheterization. These patients were found to have severe aortic regurgitation and were recommended for surgery.

It is possible that these three patients would have been fol-

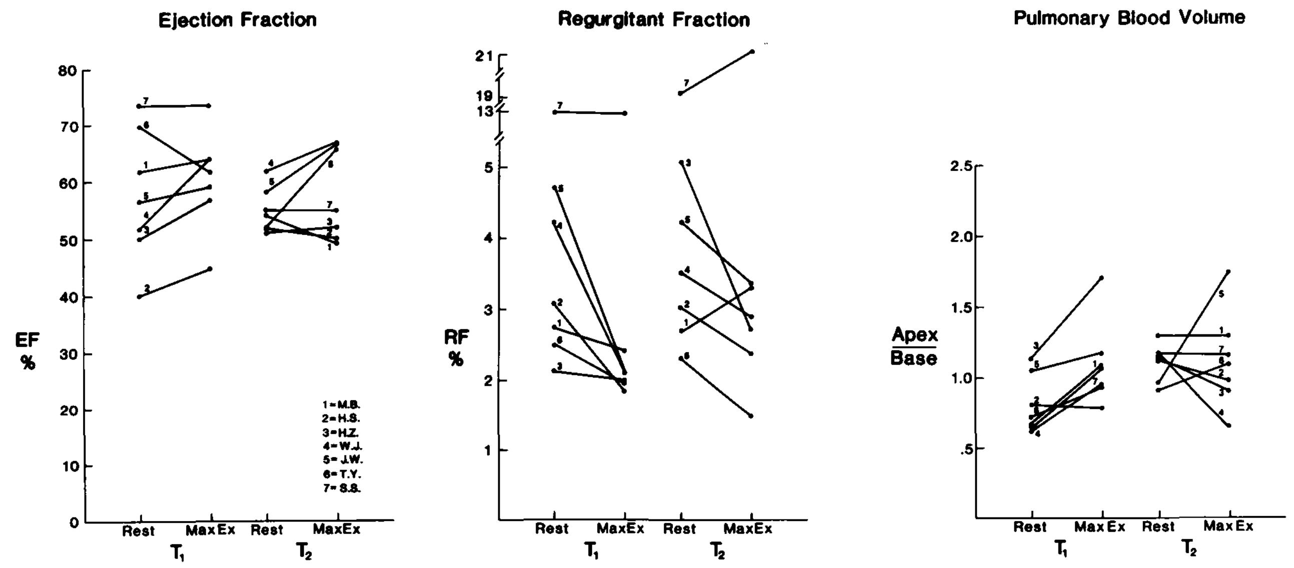

FIG. 3. Individual patient data obtained from GBPS: ejection fraction (EF), regurgitant fraction (RF), and pulmonary blood volume (PBV). These data demonstrate change in ventricular function parameters from study one (T_1) to follow up study two (T_2) for rest, and maximum exercise. The numbers 1–7 represent the patients in the study. Patients 1 and 7 had a decrease in resting EF at time two. Patients 1, 2, and 7 had a decrease in EF with exercise at time two. Patients 1 and 7 had an abnormal RF response to exercise at time two (an increase rather than a decrease). Rest PBV increased in patients 1, 2, and 7 at time two while exercise PBV fell in patient 2 and did not change in patients 1 and 7.

lowed clinically for a much longer period of time prior to surgery, resulting in potentially more severe or irreversible changes in ventricular function. However, because they had routine GBPS at their six month clinical checkup with subsequent recommendation for cardiac catheterization, they were probably saved from these potential problems.

Thus, physiological parameters which can be measured on GBPS can be effectively used to follow patients and help to determine therapeutic intervention in patients with cardiac diseases, which ultimately lead to compromise of ventricular function. It is our recommendation that rest and exercise GBPS be used routinely to follow patients with aortic valvular disease, and that parameters other than ejection fraction be routinely evaluated.

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