Radionuclide Ventricular Function Studies

New England Nuclear

North Billerica, Massachusetts

Continuing Education Committee

Technologist Section, Society of Nuclear Medicine

This is the fourth and final article in the nuclear cardiology series. After reading and studying this article, the nuclear medicine technologist will be able to: (1) compare and contrast radionuclide first-pass and gated equilibrium ventricular function studies including parameters measured, instrumentation, computer methods, and procedural details, and (2) discuss basic normal and abnormal results including ejection fraction, ventricular volumes, and wall motion.

Like other radionuclide cardiac studies, radionuclide function studies are noninvasive, providing valuable information without the attendant risks and relatively high radiation dose of cardiac catheterization. However, unlike thallium-201 and Tc-99m pyrophosphate imaging which "visualize" left ventricular myocardial perfusion and myocardial infarction respectively, the ventricular function study demonstrates global and regional performance information about the cardiac chambers.

Basics of Ventricular Function

Assessment of left ventricular function has long provided the cardiologist with some of the most useful measures of cardiac status. The traditional parameters of ventricular function used by clinicians for such assessment include heart rate, cardiac output, left ventricular end diastolic pressure, stroke volume, and ejection fraction.

Determining Factors

The three major determinants of ventricular function are preload, contractility, and afterload. Understanding these related concepts requires some knowledge of their interrelationships.

Preload refers to the extent of filling of the ventricles at the end of diastole. It is a function of the end-diastolic pressure and end-diastolic volume. As preload is increased, there is an increase in the stroke volume (the volume of blood ejected from the ventricle) or stroke work performed by the left ventricle. This characteristic of cardiac performance is known as the Starling principle, which states: "The force of cardiac contraction increases in proportion to the degree of diastolic stretch of the myocardial fibers." This relationship tends to plateau in normal patients when the end-diastolic pressure is about 15 mm of mercury. Subsequent increase in preload may result in declining ventricular function.

Contractility, which is the intrinsic ability of the myocardium to contract and may be gauged by the rate of pressure rise within the ventricle during isovolumic systole, can alter the response to a given preload. Thus, factors such as digitalis administration or catecholamines, which increase contractility, will increase the response to a given preload, and factors which depress contractility will diminish the response to a given preload.

Afterload is defined as left ventricular systolic wall stress, and is commonly represented by the systolic arterial pressure. With acute increase in arterial pressure, there is increased stress against which the ventricle contracts and thus, a decrease in the rate of blood ejected from the left ventricle. When this occurs, there is a normal compensatory response of the ventricle, which involves an increase in the preload in order to maintain normal stroke volume. Each ventricle has a limit of preload reserve that can be called upon when there is increased afterload. This reserve can be increased by increasing contractility. In patients with myocardial disease, there is a reduced preload reserve. Thus, these patients are not able to maintain normal ejection of blood with an increase in afterload.

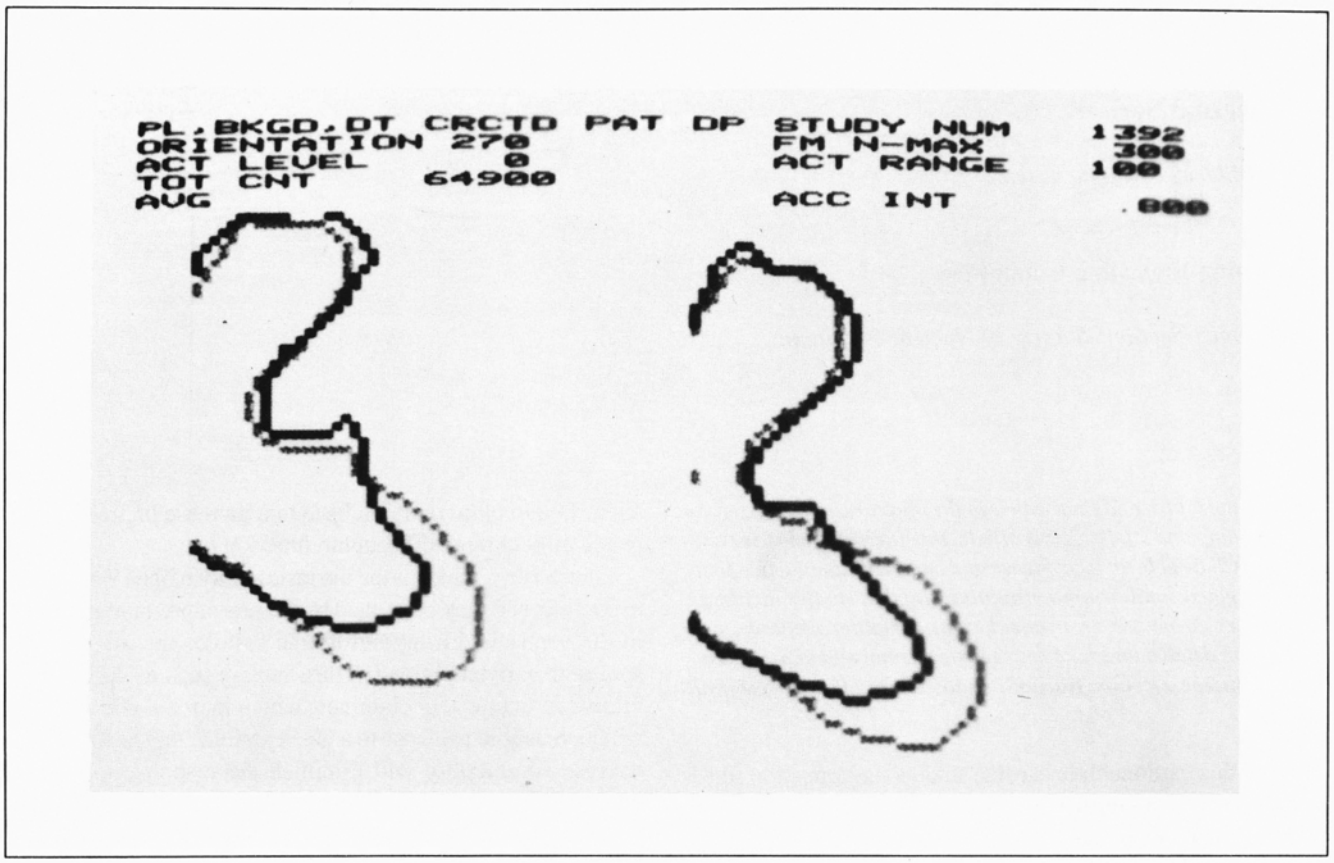
Cardiac Output

In normal resting subjects, 25% of the total cardiac output goes to the splanchnic bed and 20% goes to the renal circulation; the brain receives approximately 12% while the coronary blood flow accounts for approximately 4%. During exercise, vasodilatation in muscle beds permits flow to the involved muscles to increase from about 20% to 50%, while flow to the splanchnic and renal beds drops proportionally.

The increase in cardiac output that occurs with exercise is due to sympathetic stimulation, which leads to increased heart rate. At the same time, increased sympathetic stimulation causes increased sympathetic tone in the veins, which augments venous return to the heart and thus increases preload.

Ejection Fraction and End-Diastolic Volume

One of the most widely accepted measures of left ventricular function is the ejection fraction, the ratio of stroke volume



		ID: 030881	
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HT(IN): 71	WT(LB) 195	BSA(M**2): 2.11	
CASE #	VIEW: ANT	MD: L.BROWN	
MEDICATION:			

CLINICAL DATA:	REST	STRESS	
BLOOD PRESSURE:	124/80	190/110	MM HG
HEART RATE:	77	137	BPM
TARGET RATE:		165	BPM
WORK LOAD:		600	KPM
EXERCISE DURATION:		7.2	MIN
EXERCISE SYMPTOMS:			

CLINICAL RESULT:			
LV EF:	63	70	%
LV EF(REP CYCLE):	63	69	%
LV ED VOLUME:	112.1	109.3	ML
LV ES VOLUME:	41.5	32.8	ML
STROKE VOLUME:	70.6	76.5	ML
CARDIAC OUTPUT:	5.4	10.4	L/MIN 2
CARDIAC INDEX:	2.5	4.9	L/MIN/M
PULMONARY MTT:	7.2	3.5	SEC
PUL.BLOOD VOL.:	653.0	611.7	ML 2
PUL.B.V.INDEX:	309.5	289.9	ML/M

WALL MOTION REPORT:

FIG. 1. This study demonstrates normal left ventricular wall motion at rest and during erect bicycle stress. The end-diastolic perimeter (gray) is superimposed on the end-systolic perimeter (black).

(end-diastolic volume minus end-systolic volume) to end-diastolic volume. This volume represents the fraction of blood in the ventricle that is ejected per beat.

A reduced ejection fraction has been found to indicate a lower survival rate in medically treated patients with coronary artery disease, valvular heart disease, and primary cardiomyopathy, as well as in patients undergoing coronary artery bypass grafting, aneurysm resection, or valve replacement. Interestingly, the survival rate is similar whatever the etiology of left ventricular dysfunction. This makes ejection fraction a valuable, but nonspecific, measure of ventricular function.

The end-diastolic volume is an additionally important parameter of ventricular function which often helps in interpreting an ejection fraction abnormality. For example, in patients with valvular regurgitation, the ejection fraction may be normal, but overload will be indicated by increased diastolic volume. Among patients with coronary artery disease who have a depressed ejection fraction, those with larger end-diastolic volumes have a worse prognosis than those with smaller end-diastolic volumes. The common pathway for ventricular dysfunction is eventual depression of ejection fraction with an increase in end-diastolic volume. These manifestations may be reversible with successful medical or surgical correction of the cause of the dysfunction.

Chronic Compensatory Mechanisms

Measurement of ventricular volume also permits analysis of the chronic compensatory responses of the heart to differing loads. In chronic pressure overload, such as occurs with aortic stenosis or systemic hypertension, the main compensatory mechanism is ventricular hypertrophy with little or no dilation. This compensatory response maintains the ejection fraction or the fraction of the end-diastolic volume ejected in systole. With severe chronic pressure overload, the myocardium may "fail" and at this point the ventricle begins to dilate and the ejection fraction begins to fall.

The response to chronic volume overload is different. In these patients, the end-diastolic volume increases in relation to the volume overload, while the ejection fraction is maintained. The thickness of the muscle increases in proportion to the volume overload. When these patients are compensated, they also maintain a normal ejection fraction. When chronic volume overload results in "failure," the end-diastolic volume rises further and the ejection fraction is the final common predictor of myocardial failure.

Exercise Responses

Studies have demonstrated a significant difference in the ventricular volume responses to exercise in patients with and without coronary artery disease. For this reason, patients are often stressed to unmask abnormalities of left ventricular function.

In normal patients, the increased stroke volume and cardiac output that accompany exercise are met by a reduction in the end-systolic volume without much change in the end-diastolic volume. As a result, the ejection fraction tends to rise. In contrast, patients with exercise-induced ischemia have markedly increased end-diastolic volume and their end-systolic volume may become larger than normal. Thus, in these patients, stroke volume is maintained by drawing on preload reserve. Angiographically, this is manifested as a reduction in the ejection fraction. The parameter that best distinguishes patients with coronary disease is end-systolic volume, because there is overlap between normal patients and those with disease in both end-diastolic volume and ejection fraction response.

Wall Motion Abnormalities

Regional wall motion abnormalities have been classified subjectively as hypokinesis (reduced systolic motion), akinesis (no systolic motion), and dyskinesis (systolic outward motion). Abnormal wall motion may be due to either regional ischemia or infarction. This has great clinical importance because an abnormality due to infarction will not show improvement following bypass surgery. To assess this in the catheterization laboratory, some investigators have performed sequential left ventriculograms following interventions such as nitroglycerin administration or post-premature ventricular beat augmentation. They suggest that ischemic but viable segments demonstrate improved wall motion, while infarcted areas do not.

A myocardial infarction may result in regional abnormalities of wall motion or a ventricular aneurysm may develop (which is visualized as an akinetic or dyskinetic segment). Myocardial infarction can also result in a ventricular septal defect or mitral regurgitation, demonstrating a volume overload pattern.

Ventriculography may suggest the diagnosis of hypertrophic cardiomyopathy. In patients with this disease, there is minimal or no dilatation of the left ventricle and there is an increase in segmental hypertrophy such that the ejection fraction increases. This can also be seen as a marked thickening of the myocardium, particularly noticeable in the septal region. The best way of diagnosing this condition is by echocardiography, although characteristic findings may be identified by intraventricular pressure recording.

Radionuclide Techniques

Ventricular volumes, ejection fraction, and exercise hemodynamics are the most important measures of ventricular function. Except for intracardiac pressures, radionuclide techniques can reliably, accurately, and noninvasively yield these measures for both the left and right ventricle. Thus, many cardiac conditions which have previously required catheterization and hospitalization for diagnosis and evaluation can now be assessed noninvasively.

Radionuclide ventricular function studies can be broadly divided into two types: first-pass studies and gated equilibrium studies. The first-pass technique utilizes only the initial transit of a radionuclide bolus as it passes through the central circulation. The procedure requires only about 30 seconds for data acquisition and does not require a great deal of patient cooperation. The short acquisition time and relative lack of dependence on patient cooperation make the first-pass technique ideal for assessment of cardiac performance in rapidly changing physiologic states, such as exercise, and in critically ill

patients unable to remain motionless under a scintillation camera for a long period.

In the gated equilibrium technique, the R-wave of the electrocardiogram is used to initiate the data collection cycle. The patient may sometimes remain under the camera for 10 to 20 minutes while data are collected.

Both of these techniques provide similar information on ventricular function and each has particular advantages and disadvantages. The choice of which technique to use is usually dictated by the instrumentation available, the clinical setting, the overall patient population at an institution, and, of course, physician experience and preference.

First-Pass Ventricular Function Studies

Today's instrumentation allows determination of pulmonary transit time, cardiac output, estimated chamber size, ventricular wall motion defects, and detection of anatomic abnormalities such as shunts.

Positions and Views

First-pass studies can be performed with the patient either supine or upright. Anterior, left anterior oblique, and right anterior oblique views are possible. Position variation is allowed since the activity is limited to the cardiac chamber through which the bolus is passing at any one moment. This temporal and spatial separation is also an advantage in analyzing regional wall motion and enables quantitative evaluation of both right and left ventricular function with a single study.

Injecting the Bolus

Injection technique is critically important in first-pass studies. The study is dependent on homogeneous mixing of the radioactive tracer with the blood, so that changes in count rate correspond directly to changes in ventricular volumes. The quality of the injection should be assessed for each study, analyzing the transit of activity through the superior vena cava visually and quantitatively, which ideally should be less than 3 sec.

Radiopharmaceutical Selection

Technetium-99m labeled radiopharmaceuticals that remain sufficiently long within the intravascular space can be used for a first-pass study. High-specific-activity [^{99m}Tc] pertechnetate or labeled human serum albumin are most frequently used for single studies. When multiple views or serial studies (such as rest and exercise) are to be performed, the first injection may use Tc-99m DTPA or sulfur colloid, which are rapidly cleared from the blood stream. For the second injection, [^{99m}Tc] pertechnetate may be used. First-pass ventricular studies can also be combined with acute infarct imaging, using a bolus injection of Tc-99m stannous pyrophosphate for the first-pass study and delayed static imaging. The recommended dose for first-pass imaging is 10–25 mCi per injection.

Imaging

Scintillation camera characteristics can markedly affect the quality of first-pass studies. The camera system must be capable of providing adequate temporal and spatial resolution with acceptable counting statistics. Some new Anger scintillation cameras can obtain count rates of about 100,000–200,000 counts/sec, after which dead-time losses and data distortion occur. The multicrystal camera permits much higher count rates, as high as 450,000 counts/sec without significant dead-time losses.

Frame Rate

The acquired data is stored either in list mode or frame mode on magnetic disk at 20 to 25 frames/sec. This allows accurate analysis of the high-frequency components of the ventricular time-activity curves. At higher heart rates, a given framing rate means fewer counts per frame. Many departments attempt to resolve this problem by using a higher-sensitivity collimator or by increasing the radionuclide dose.

Background Correction

Subtraction of background activity from overlying and underlying blood-containing structures is important for accurate determination of parameters of left ventricular function. Numerous approaches to left ventricular background correction have been described. A widely used method developed by Marshall et al. uses the time-activity curve. A series of frames is selected just prior to the first visible left ventricular beat on the time-activity curve to provide a constant background image that represents overlying and scattered radiation at a time when all of the radionuclide is in the left atrium and lungs. This background correction enhances the definition of left ventricular edges.

Region of Interest

Once the data has been collected and reviewed, the operator defines a region of interest (ROI) over the end-diastolic left ventricle. The activity in this region is analyzed only during the time when it is in the left ventricle. Careful definition of the left ventricular ROI is crucial since over- or under-estimation results in inaccurate determinations.

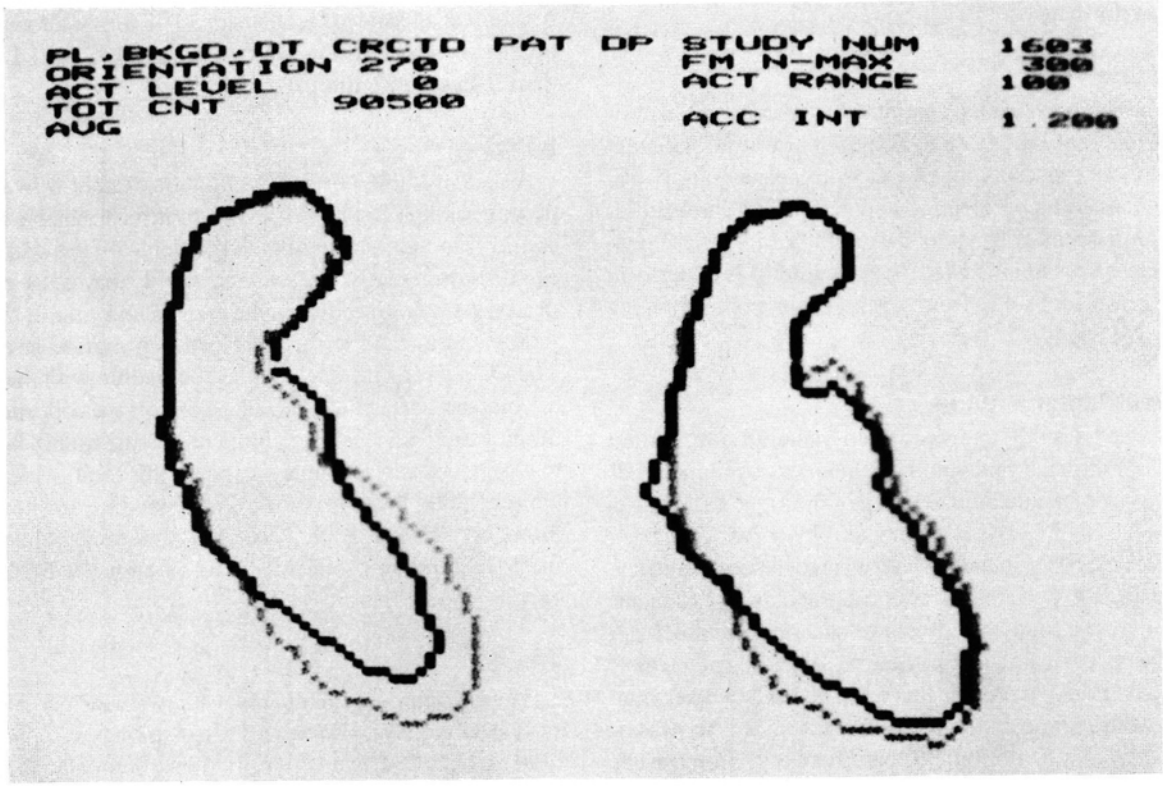
Assessing Global Ventricular Function

Once the region of interest has been defined and the background activity subtracted, the left ventricular ejection fraction is calculated as the difference between end-diastolic counts (EDC) and end-systolic counts (ESC), divided by the end diastolic counts:

$$\text{Ejection fraction} = \frac{EDC - ESC}{EDC}$$

Counts can be determined using either an average of several beats or the summed cardiac cycle produced by several beats added frame by frame. Only the beats at the peak of the time-activity curve should be used for data analysis. In patients with premature ventricular contractions, the premature beat and the post-premature beat should be excluded from the analysis.

Other indices of left ventricular performance can also be calculated from the first-pass data. The shape of the ventricular function curve can tell much about the rate of ventricular



AGE: 54 SEX: MALE DATE: 10/15/78
HT(IN): 68 WT(LB): 184 BSA(M**2): 2.03

HISTORY: ANGINA UPON EXERTION

CLINICAL DATA:	REST	EXERCISE	
BLOOD PRESSURE:	136/80	190/96	MM HG
HEART RATE:	74	164	BPM
TARGET RATE:	-----	160	BPM
WORK LOAD:	-----	500	KPM
EXERCISE DURATION:	-----	8	MINUTES
EXERCISE LIMITING SYMPTOMS:	-----	ANGINA	

CLINICAL RESULT:	REST	EXERCISE	
LV EF:	57	34	%
LV ED VOLUME:	158	194	ML
LV ES VOLUME:	68	128	ML
STROKE VOLUME:	90	66	ML
CARDIAC OUTPUT:	6.6	10.8	ML/MIN 2
CARDIAC INDEX:	3.25	5.3	ML/MIN/M
PUL. BLOOD VOL.:	785	845	ML 2
PUL. B.V. INDEX:	387	416	ML/M

WALL MTN.(REST): NORMAL CONTRACTION

WALL MTN.(EXER): ANTERIOR AKINESIS WITH ANTERO-LATERAL & INFERIOR HYPO-KINESIS.

FIG. 2. This abnormal study in a patient with exertional angina demonstrates markedly impaired wall motion on exercise. Note how the derived ejection fraction is lower on exercise than at rest.

emptying and filling information that may indicate valvular or compliance abnormalities which can affect global left ventricular performance.

Wall Motion

A summed representative cardiac cycle permits visual evaluation of regional wall motion. A more accurate assessment of wall motion, especially in patients with coronary artery disease, is obtained by performing additional first-pass studies in other projections or by use of a dual-angle biplane collimator. An alternative to multiple first-pass studies is to perform a gated equilibrium study from several projections following the first-pass study.

Right Ventricular Studies

The first-pass study can also yield valuable information about right ventricular function. If the anterior position is used, there may be some anatomic overlap of the right atrial background to the right ventricular time-activity curve. To correct for this, select a background ROI adjacent to the right ventricle at the interface between the right ventricle and the right atrium. Then, generate a time-activity curve and subtract this from the right ventricular time-activity curve. After this procedure, the right ventricular function curve can be used to determine the right ventricular ejection fraction and to assess right ventricular regional wall motion. Because there is less noncardiac activity during the right heart phase, background correction is less of a problem than the left heart phase. Other projections, such as a right anterior oblique or the use of a slant hole collimator, may provide a better view of the right ventricle.

Gated Equilibrium Ventricular Function Studies

The gated equilibrium, or gated blood pool, study differs fundamentally from the first-pass technique in that data is collected continuously over hundreds of cardiac cycles. This data is summed for discrete intervals of each cycle to give an average, representative picture of the patient's cardiac function. Although this approach may result in a loss of some rapid dynamic information that is preserved on first-transit studies, the gated technique has images containing more counts.

Radiopharmaceutical Selection

Equilibrium blood pool studies require a radiopharmaceutical that remains within the vascular space for the duration of the study. Although Tc-99m labeled albumin was initially used for gated blood pool imaging, in vivo or in vitro labeling of red blood cells with Tc-99m is the preferred radiopharmaceutical. In vivo or in vitro labeling provides a higher target-to-background ratio than is obtained with Tc-99m labeled albumin, which tends to slowly leak out of the vascular space and produce excessive background activity, especially in the liver.

The procedure for modified labeling of the red cells is relatively simple:

Intravenously inject a vial of saline-reconstituted stannous pyrophosphate which is allowed to circulate for about 20 minutes, so that the stannous ion binds to the red cells. Five to eight ml of blood is drawn into a syringe containing 1 ml ACD and 20 mCi [^{99m}Tc] pertechnetate. The blood is placed on a rotator and allowed to incubate for 10–15 min to allow the technetium to bind to the red blood cells. The labeled blood is then injected into the patient.

Imaging

A standard field-of-view scintillation camera with a general purpose or high resolution collimator is most suitable for gated equilibrium imaging. With a large field-of-view camera, the significant amount of extracardiac activity may cause excessive dead-time loss. In addition, the camera and yoke of the large-field cameras tend to interfere with leg motion at exercise. The ECG gating device must be compatible with the camera or computer, depending on which controls the collection cycle. Some gating devices have limits on the maximum heart rate to which they can accurately respond; this limit, which should approach 200 beats/min for exercise studies, must be determined in advance. Both a strip chart recorder, to document the ECG, and an oscilloscope, to monitor the ECG during exercise studies, are essential.

Views

Gated blood pool imaging is usually performed in the left anterior oblique (LAO) view. This position best separates the right and left ventricles, thus providing optimal visualization of the septum. The left atrium, aortic arch, mitral valve plane, and the lateral walls of both ventricles are also well seen in this view. The anterior view visualizes the right atrium, tricuspid valve plane, right ventricle, pulmonary artery and outflow tract, and the anterolateral and apical portions of the left ventricle. A modified left anterior oblique view, using a 25–30 degree caudally tilted slant hole collimator or using a parallel hole collimator with caudal camera tilt, affords greater separation between atria and ventricles, improving ventricular visualization by imaging the ventricles approximately perpendicular to their longest axes. Additional views, such as the left lateral, 70° LAO, or left posterior oblique may also be used if desired.

Acquisition, Storage, Display

The cardiac cycle is divided into 14 to 100 images depending on computer capabilities and personal preference. Ensuring an adequate ECG gating signal is an important part of this procedure, since all the data collection depends on this signal. The actual placement of the electrodes may be critical and should not lie in the field between the scintillation camera and the heart.

If the gating sequence is proper, all frames in the cineangiogram except the last should have approximately the same number of counts. The last frame normally has fewer counts due to minor fluctuations in heart rate and, thus, is usually discarded. Many computer systems allow data to be discarded if the R-R interval is outside certain limits or if the study can be acquired in list mode and framed up for a specific R-R time interval.

This multiple gated blood pool study provides a vast amount

of anatomic, temporal, and functional information previously unobtainable by noninvasive means. Computer systems also permit data display in real time as an average cardiac cycle cineangiogram, enabling more precise visual interpretation of the data as well as objective computer-assisted data analysis.

Background Correction

The background contribution on an equilibrium image is significant. Background correction is just as essential for gated blood pool imaging as it is for the first-pass study. Unfortunately, there is no single, widely accepted method to accurately correct for background. Current approaches tend to rely greatly on subjective judgment. For example, on the LAO image the operator assigns a region of interest inferior and lateral to the ventricle within the lung or any area that appears to be representative of the background surrounding the heart. This region should show a constant count for each frame of the study. A rise and fall in counts could indicate that the region of interest overlies a major vascular structure which would give a less accurate background value. In such a case, the operator should select another representative-background region. The background value ultimately chosen is expressed in counts per pixel. This value is then subtracted from every pixel in each image to obtain the background-corrected images.

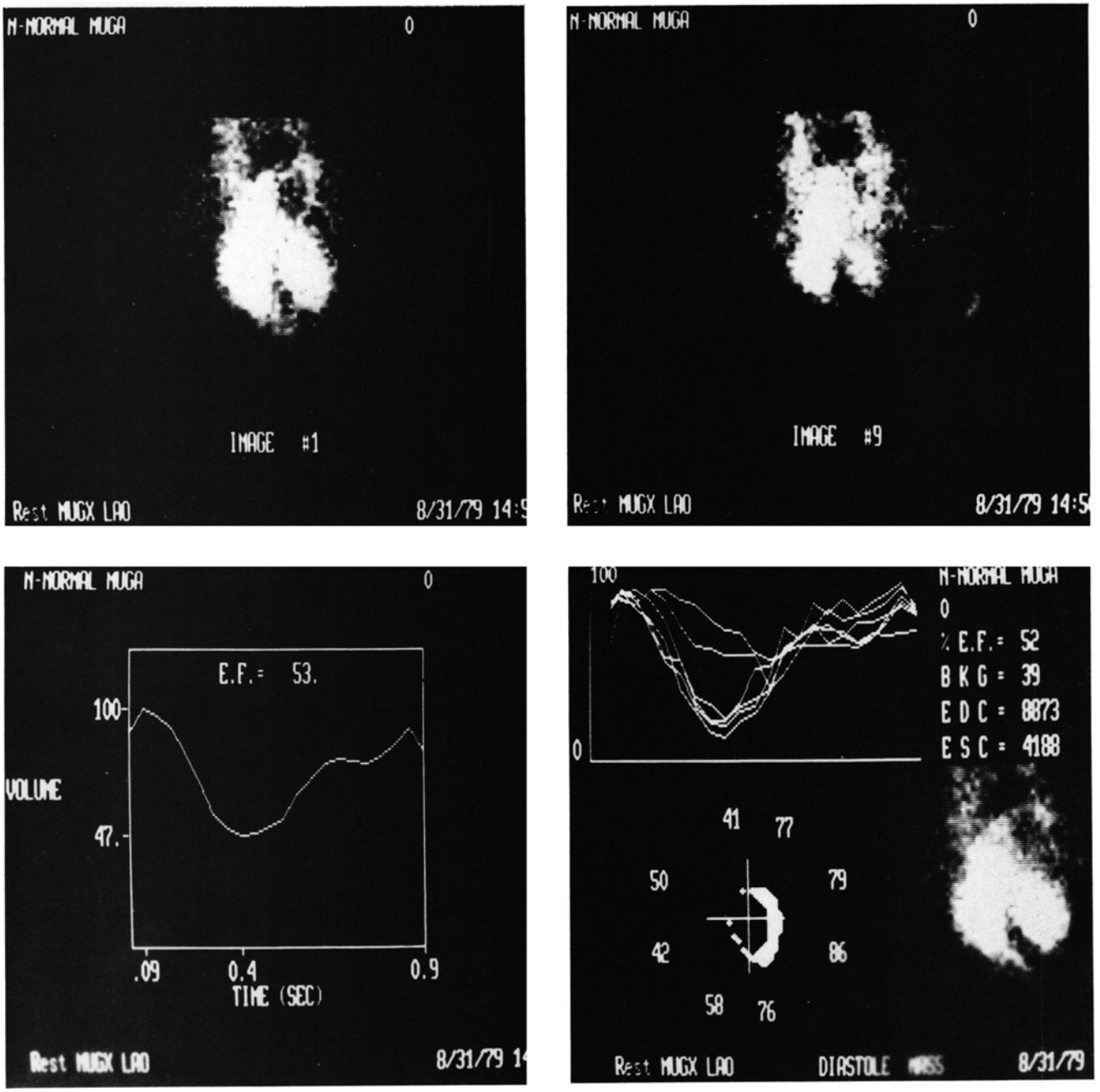


FIG. 3. This normal gated equilibrium study, performed at rest, shows end-diastolic and end-systolic images, as well as derived ejection fraction.

Region of Interest

Following the background correction procedure, the operator must select an ROI over the ventricle to be analyzed. Care is required not to include the atrium, not to cross over the septum into the other ventricle, and not to include the outflow tract of the respective ventricle. This is done for both the end-diastolic and end-systolic images.

Viewing the Study

Gated studies are normally interpreted in two phases: a subjective assessment that includes chamber sizes, configuration, and regional wall motion throughout the cardiac cycle, followed by a quantitative determination of ventricular function (Figs. 3 and 4).

The subjective interpretation begins by viewing the cineangiogram at a variety of cycling rates. Varying the contrast during viewing enables optimal visualization of all cardiac structures.

Those who have never viewed a gated blood pool cineangiogram before may be initially surprised to see that the four chambers of the heart do not contract at the same time. Remember: while the ventricles are in their systolic phase, the atria are in their diastolic phase, and vice versa. Thus, the ventricles normally contract simultaneously.

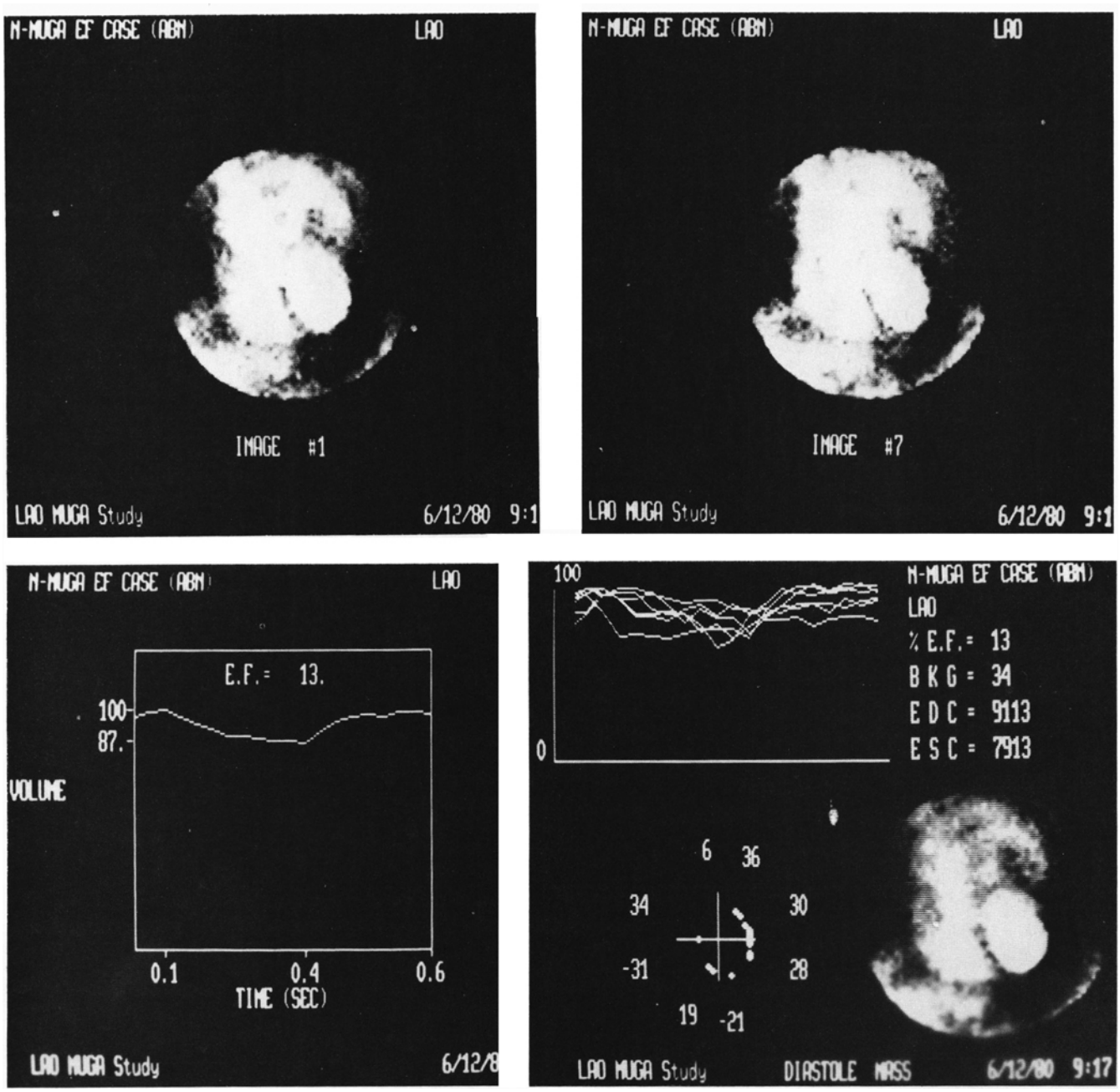


FIG. 4. This abnormal study, also performed at rest, demonstrates diffuse hypokinesis and an extremely low ejection fraction. Such findings are consistent with, but not diagnostic of, severe coronary disease.

Right Atrium

During diastole, the right atrium is spherical in shape and contains about 60 ml of blood. If the patient has right atrial enlargement, it will appear as a bulge in the lateral and superinferior dimensions of the chamber. Atrial systole lasts only a brief time at a resting heart rate.

Right Ventricle

The right ventricle appears triangular in shape and, at end-diastole, has a volume of approximately 165 ml in a 70-kg adult. During systole, the ventricle may appear to rotate as it contracts. With acute increase in volume load, as often occurs in cases of right ventricular infarction, when right heart function is impaired, the ventricle compensates by dilating. The normal right ventricular ejection fraction is 40 to 60%.

Left Atrium

The left atrium and mitral valve plane are best seen on a 30 degree left posterior oblique view. On the usual 40 degree LAO view, the left atrium appears superior to the left ventricle and inferior to the left pulmonary artery. The normal chamber volume is about 40 ml.

Left ventricle

The left ventricle is the hardest working of the heart's chambers. It must generate three to six times as much pressure as the right ventricle, and, accordingly, its walls are approximately three times as thick as those of the right ventricle. This thickness is visualized on the blood pool image as a halo of decreased activity around the chamber. The left ventricle contains about 150 ml of blood at end-diastole. Normally, 55 to 75% of this volume is ejected with each beat. The papillary muscles may be visible as filling defects within the chamber; these defects are usually more apparent on the LAO view. The motion of the antero- and posterolateral surfaces is usually greater than that of the septum, the apex, and the inferior wall. The septum should thicken during systole and contract toward the left ventricle.

Ventricular Function Calculations

Quantitative determinations of ventricular function are possible after correction of the data for background activity. As described before, this procedure requires some subjective judgment on the part of the operator: a representative background ROI is selected lateral to the ventricle, in the lung, and the average counts per pixel in the ROI are then subtracted from all points in each of the image frames.

Following the operator's definition of a ROI over the ventricle, the computer generates a time-activity curve using the frames that represent the cardiac cycle. The operator must select those frames which best represent end-diastole and end-systole. Then, left ventricle ED and ES ROI's can be assigned and the ejection fraction can be calculated using the same formula that is applied in the first-pass study.

The right ventricular ejection fraction may also be calculated from the gated blood pool data. However, this calculation requires particular attention to the position of the right atrium. In the 40° LAO view, the atrium may lie behind the ventricle, particularly when the patient is in the supine position. Failure to take into account superimposed right atrial activity may give an erroneously depressed ejection fraction. Maneuvers to correct for right atrial activity include tilting the camera head somewhat caudad in order to separate the two chambers better and exercising care in assigning the ROI to exclude the top of the ventricle.

Exercise Blood Pool Imaging

Exercise blood pool studies may be performed using either the first-pass or the equilibrium technique. These studies are useful in disclosing abnormalities in cardiac function that become apparent only with physiologic stress. Thus, most investigators report that exercise blood pool imaging is a highly sensitive means of detecting coronary artery disease, which most often results in a reduced exercise ejection fraction response and regional wall motion abnormalities.

Exercise Table and Ergometer

The exercise table and ergometer must remain as stable and motionless as possible during the exercise. To prevent excessive motion artifact, the patient should be restrained on the table during exercise, with his feet well anchored to the ergometer pedals. The ergometer should be attached to the imaging table in a way that does not interfere with imaging and permits the patient to exercise freely. The ergometer must be appropriately calibrated for graded exercise to permit workload monitoring and rpm measurement.

As with any type of exercise testing, an experienced physician, able to monitor the patient for signs of distress and practiced in cardiopulmonary resuscitation, must be in attendance at all times. Appropriate emergency equipment and medications must be at hand.

Patients should be thoroughly briefed on the procedure so they understand what is expected of them and what they can expect to occur during the test. Letting patients practice pedaling before the study gives them a "feel" for the procedure.

To minimize heart rate variation and fatigue within an imaging interval, the data collection period should be as short as possible. An example stress study might use a 2-minute data collection period with the patient pedaling at a rate of 50 to 70 rpm during this time. This 2-minute period permits sufficient time within the 3-minute intervals of the graded exercise protocol. The heart rate tends to plateau after 60–90 sec of a constant workload, which gives about 1.5–2 min of a relatively stable heart rate for data collection. Because the framing windows are set at the start of a data collection period, based on a heart rate determined at that time, significant variation in heart rate during the data collection period will result in an invalid study.

Procedures, Protocols, Pitfalls

The exact procedures for background correction, region of interest identification, ventricular edge tracking and data presentation are unique to each laboratory. They depend on the kinds of information the physicians expect from the study and

the type and sophistication of the instrumentation. This makes it somewhat difficult to go into much greater detail when discussing these procedures.

In performing radionuclide ventricular function studies, the following points must be kept in mind:

- ☐ You can't assess the technical adequacy of your studies unless you understand the dynamic physiology that is displayed on your screen. In addition to the ejection fraction, regional wall motion should be evaluated.
- ☐ Many factors can contribute to poor quality images and erroneous quantitated values. Not only should patient motion, patient anatomy, radiopharmaceutical quality, and instrumentation characteristics be taken into account, but the adequacy of the gating signal, framing intervals, and the occurrence of arrhythmias must be considered. The incidence of arrhythmias and the problems of extreme patient motion during exercise are particularly important, requiring constant monitoring.
- ☐ Exercising a cardiac patient always involves some degree of risk, necessitating the attendance of an experienced physician and emergency equipment and medication.
- ☐ The computer software for ventricular function analysis is not completely automatic. Quality control is the responsibility of the technologist. The computer can make mistakes. Insufficient counts, for instance, may lead to serious errors in edge tracking which, in turn, can lead to major errors in quantitated value. The quantitative data should agree with the visual display; check the values manually if they do not.

Suggested Readings

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