Detection of Left Atrial Myxoma
By Gated Radionuclide Cardiac Imaging

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SUMMARY Gated radionuclide cardiac blood pool scans (GCS) of end-systole and end-diastole or eight images subtending the entire cardiac cycle were performed on seven patients with left atrial myxomas documented by pulmonary cineangiography with left atrial follow-through. The echocardiogram was either suggestive or diagnostic in all patients. In addition to demonstration of the tumor (6 patients), the GCS detected three patterns of tumor motion: 1) a defect which moved from the left atrium in end systole to the left ventricle in end diastole (2 patients); 2) a defect which remained within the region of the left atrium but decreased in size between end diastole and end systole (3); and 3) a defect which was observed within the region of the left ventricle in end diastole but disappeared in end systole (1). Thus, the GCS is a noninvasive method for detection and evaluation of motion of left atrial myxomas.

THE DIAGNOSIS OF LEFT ATRIAL MYXOMA has been greatly facilitated in recent years by echocardiography. However, it is occasionally difficult or impossible to obtain an adequate echocardiogram and the echocardiogram may not always be diagnostic of left atrial tumor. The gated cardiac blood pool scan is technically possible in virtually any patient and provides an image of all the cardiac chambers. This method has been used in the detection of left atrial myxoma in isolated cases but its general application in the clinical evaluation of subjects with possible left atrial myxomas has not been defined. The following study was undertaken to demonstrate the utility of the gated cardiac blood pool scan in the diagnosis of left atrial myxoma.

Methods

Seven patients with left atrial tumors demonstrated by echocardiography and/or cineangiography underwent gated cardiac blood pool scanning. Twenty μCi of electrolytically bound technetium-99m human serum albumin (99m TcHSA) were injected intravenously. After 2 min for equilibration of the tracer within the blood pool, an Anger camera equipped with a Low Energy All Purpose (LEAP) parallel hole collimator was positioned over the supine patient's precordium. Three views were obtained: a 30° right anterior oblique, an anterior, and a 50° left anterior oblique. A physiological synchronizer† was used to gate image collection with the electrocardiogram. End-diastolic images were collected for 80 msec beginning with the onset of the electrocardiographic QRS complex and systolic images were collected for 80 msec beginning at the peak of the T wave (fig. 1). In four patients, the cardiac cycle (R-R interval) was divided into eight equal intervals to produce sequential images in one or more projections (fig. 2). Images were stored in the core of a PDP-9‡ computer system, processed to obtain edge enhancement, and displayed on a high resolution oscilloscope. * Systolic and diastolic images or eight gated images were displayed sequentially to produce a time-motion display, and were reviewed by three observers.

Echocardiograms were performed using either a SKI-echoline 20A echograph with a Honeywell 1856 stripchart recorder or a Unirad echograph with a Honeywell 1858 stripchart recorder. Echocardiograms were independently reviewed by four observers and classified as either diagnostic or suggestive. Cineangiograms were performed with injection through a multiple side-hole NIH catheter of meglumine detriazoate* into the pulmonary artery with follow-through to the left atrium and ventricle. If three or four observers interpreted the echocardiogram as typical of left atrial myxoma, the study was called diagnostic, whereas if fewer than three of the observers interpreted the echocardiogram as typical, the study was termed suggestive.

Results

Clinical data for each of the seven patients with left atrial myxomas is summarized in table 1. In all patients in this series both echocardiogram and gated radionuclide blood pool scan were technically adequate. In five of the seven subjects, the echocardiographic examination was considered diagnostic. In two subjects the echocardiogram suggested left atrial myxoma but was not considered diagnostic. Angiography demonstrated the tumor in each of the seven patients.

An abnormal region of diminished activity was identified within the cardiac blood pool in six of seven patients with left atrial myxoma. In all six patients in whom the myxoma could be identified, it was demonstrated in the 30° right anterior oblique projection. In four of the six patients, the myxoma was also identified in the left anterior oblique and in the anterior projections.

Three patterns of tumor motion were recognized on the gated blood pool scan.

1) A filling defect within the region of the left atrium in end systole and in the region of the left ventricle in end diastole was observed in two subjects. The cineangiogram demonstrated a mobile tumor which prolapsed entirely into
the left ventricle in end diastole and a mobile tumor on a long stalk was verified at surgery. In both the echocardiogram was diagnostic.

2) A filling defect which remained within the region of the left atrium but decreased in size in end diastole was observed in three patients (fig. 3). Cineangiography demonstrated that only a small portion of these tumors prolapses into the left ventricle in end diastole. The explanation for the decrease in diastolic size of the atrial filling defect on the blood pool scan remains speculative. It is possible that the small portion of the tumor which prolapses into the left ventricle separating from the bulk of the tumor in the left atrium becomes obscured by the left ventricular blood pool and is not resolved by this radionuclide technique. One of these patients had a suggestive echocardiogram while the other two had diagnostic ultrasound studies.

3) In one patient the tumor defect was observed only within the left ventricle in the end-diastolic right anterior oblique image (fig. 4). Substantial enlargement of the right atrium and ventricle was observed on the left anterior oblique gated scan image. These right sided chambers overlay and thus obscured the left atrial blood pool. On the cineangiogram this tumor appeared to be dumb-bell shaped and to prolapse into the left ventricle in end diastole. The echocardiogram was not diagnostic in this patient.

In one patient the myxoma could not be identified on gated scan. The right sided blood pool was the largest in this series and may have contributed to the difficulty in defining this tumor. The pulmonary cineangiogram in this patient demonstrated a remarkably lobulated tumor with multiple crevices.

In four patients eight sequential gated images subtending the entire cardiac cycle were obtained for dynamic motion display. An example of this technique is illustrated in figure 2. These images were directly compared with their corresponding cineangiographic frames. The tumor is well

<table>
<thead>
<tr>
<th>Patient initials</th>
<th>Age</th>
<th>Sex</th>
<th>Presentation</th>
<th>Echocardiogram</th>
<th>Pulmonary cineangiogram</th>
<th>Surgical findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB</td>
<td>36</td>
<td>F</td>
<td>Fatigue and dyspnea for 7 months</td>
<td>Diagnostic</td>
<td>Lobulated filling defect 4 cm in diameter on a stalk which prolapses well into the left ventricle.</td>
<td>Ellipsoidal 6.5 × 4 × 3 cm LAM attached to the intra-atrial septum by a 3-4 mm stalk</td>
</tr>
<tr>
<td>DE</td>
<td>57</td>
<td>F</td>
<td>Multiple embolic episodes over an 8 month interval</td>
<td>Diagnostic</td>
<td>Lobulated filling defect 2-3 cm in diameter which moves forward in early diastole, but slightly posteriorly in end diastole associated with atrial contraction. The defect had little excursion.</td>
<td>Ellipsoidal 5 × 4 × 0.9 cm LAM attached to the intra-atrial septum on a short stalk (3mm).</td>
</tr>
<tr>
<td>VM</td>
<td>59</td>
<td>F</td>
<td>Fatigue and dyspnea for 5 months</td>
<td>Diagnostic</td>
<td>Discrete filling defect 4-5 cm in diameter which prolapses into the left ventricle in end diastole</td>
<td>Ellipsoidal (4 × 8 cm) 5 × 3 × 2 cm LAM attached to the intra-atrial septum near the fossa ovalis.</td>
</tr>
<tr>
<td>TB</td>
<td>55</td>
<td>F</td>
<td>Dyspnea for 11 months</td>
<td>Diagnostic</td>
<td>Discrete filling defect 4-5 cm in diameter which prolapses into the left ventricle in end diastole and into the left atrium in end systole.</td>
<td>Ellipsoidal 5 × 2.5 × 1 cm LAM attached to the intra-atrial septum</td>
</tr>
<tr>
<td>RA</td>
<td>61</td>
<td>M</td>
<td>Fatigue and dyspnea for 18 months.</td>
<td>Suggestive</td>
<td>Dumbbell-shaped 8-9 cm diameter filling defect occupying the entire left atrium with 5-6 cm defect projecting into the left ventricle in diastole.</td>
<td>Ellipsoidal 8 × 5 × 3½ cm filling the entire left atrium</td>
</tr>
<tr>
<td>JW</td>
<td>78</td>
<td>F</td>
<td>Fatigue, dyspnea and weight loss for 18 months.</td>
<td>Diagnostic</td>
<td>Large multilobulated defect with the appearance of multiple small defects prolapsing incompletely into the left ventricle in diastole.</td>
<td>Spherical (8 cm) 4 × 4 × 4 cm considerable enlargement of the right-sided chambers.</td>
</tr>
<tr>
<td>CE</td>
<td>59</td>
<td>F</td>
<td>Fatigue, dyspnea, orthopnea and palpitations for 2 months.</td>
<td>Suggestive</td>
<td>Lobulated filling defect 3-4 cm in diameter moving 3 cm from LA (syst.) to LV (diast.). Total length in systole 9 cm.</td>
<td>Spherical 5 × 4 × 4 cm.</td>
</tr>
</tbody>
</table>

LAM = left atrial myxoma.
defined (fig. 2, E--H) and is located within the left atrium. As diastole progresses the tumor appears to move toward the left ventricle (H in fig. 2). At the onset of systole (A in fig. 2), the defect seems to disappear as it moves rapidly back into the left atrium. Since each gate was 80 msec, such rapid motion produces blurring. During systole (fig. 2, B--D) the tumor is less readily identified and may be obscured by the larger left atrial blood pool during this phase of the cardiac cycle. Finally, with the onset of ventricular diastole, the tumor once again is easily identified.

All patients underwent surgical removal of the left atrial myxomas. One patient, E.W., a 72-year-old woman with long-standing symptoms of left heart failure and marked pulmonary hypertension preoperatively, died suddenly two weeks after surgery. Postoperative gated scans in the six surviving patients demonstrated loss of the filling defect and normal left ventricular function. Echocardiograms demonstrated normal mitral valve motion.

Discussion

Although the echocardiogram allows sensitive detection of left atrial myxoma,1,2 the specificity of this technique remains undefined. Standard M mode echocardiography does not precisely define the size, location, or mobility of the tumor. Furthermore, this ultrasound technique is occasionally quite difficult or impossible to perform due to large chest size, emphysema, or other factors.3 Two of seven echocardiograms in the present study were questionable with respect to the diagnosis of left atrial myxoma while the remaining five were diagnostic. The gated radionuclide cardiac blood pool scan provides a means of demonstrating left atrial myxoma and assessing its position, excursion, and size. Although this radionuclide approach does not suffer from the technical difficulties encountered with the echocardiogram, it may be less sensitive due to its lower resolution. Nevertheless, the technique provides an additional means of noninvasive diagnosis of left atrial myxomas which is especially useful in the face of suggestive, nondiagnostic, or technically unsatisfactory echocardiographic studies. In the present series the two patients in whom the echocardiogram was not diagnostic had filling defects on gated scan, while the one patient with a negative gated scan had a diagnostic echocardiogram.

The patient in whom the gated blood pool scan failed to demonstrate the myxoma was shown by cineangiography and surgery to have a large tumor composed of multiple small lobules. It is probable that each lobule was too small for resolution by this radionuclide technique, a formation contributing to the inability in obtaining an image of the entire tumor. In addition, the markedly dilated right ventricle

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**Figure 1.** Gated radionuclide scans were obtained after intravenous injection of 20 mCi of technetium-99m bound to human serum albumin (99m TcHSA). The Anger Camera was positioned over the precordium and an electrocardiographic synchronizer was used to allow collection of counts during diastole (during the QRS complex) and end-systole (during the latter half of the T wave). Images in end-diastole and end-systole are illustrated with the portion of the electrocardiogram used to obtain these images (shown to the left of each image) indicated by a dash. A well-defined left atrial filling defect can be seen in both end systole and end diastole.
may have further obscured the tumor. In another patient, however, the tumor was identified despite a markedly enlarged right ventricle.

Computer handling of gated cardiac blood pool data

**FIGURE 2.** Eight sequential images spanning the cardiac cycle are illustrated in a patient with left atrial myxoma obtained by gated radionuclide scan. (Scan images were obtained by dividing the R-R interval into eight equal segments [approximately 80 msec in the patient with heart rate of 90 beats/min] using the physiological synchronizer illustrated in figure 1. The first gate started with the R wave [A, end diastole] and the last gate ended with the R wave [H].) D represents end-systole (lowest frame, left hand column) and H end-diastole (lowest frame, right hand column). Note that the left atrial myxoma by scan (arrows in A and E) is poorly defined in A to D and easily defined in E to H. Thus, the tumor would not be evident in an end-systolic image in a conventionally gated study. A in early systole shows a poorly defined long filling defect above the left ventricle (LV). The comparable cineangiographic frame showed the myxoma moving rapidly into the left atrium from the LV. The 80 msec gate on the scan accounts for the blurred and elongated appearance of the myxoma. As systole progresses (B, C, and D), the tumor remains poorly defined. During diastole (E to H) a discrete filling defect is easily seen. The cineangiogram demonstrated that the tumor had reached a relatively fixed position within the LV just beneath the mitral valve.

**FIGURE 3.** A left atrial blood pool defect is well defined in systole and diastole. The defect becomes smaller and appears to move further back in the region of the left atrium in diastole. An explanation for apparent paradoxical motion of this tumor was provided by the pulmonary cineangiogram which demonstrated a mobile tumor which remained behind the mitral valve leaflets within the left atrium throughout the cardiac cycle. In diastole, the tumor moves anteriorly until end diastole when the tumor rebounds posteriorly after the atrial contraction.

may be helpful in the diagnosis of left atrial myxoma. Contrast enhancement was helpful in the patient (R.A.) in whom the myxoma was identified despite the markedly increased right sided chamber volumes. An increase in blood pool activity overlying the myxoma would tend to diminish contrast and obscure the filling defect within an underlying chamber. The eight gated scan viewed sequentially may also improve tumor detection. Figure 2 illustrates an eight gated study. Note that the filling defect is not well defined throughout systole (A–D in fig. 2), while in diastole (E–H in fig. 2) is easily defined. If collection of counts had been confined to end diastole and end systole, the gated scan might not have been diagnostic. The eight gated scan is also useful in defining tumor motion.

In conclusion, the gated blood pool scan provides a noninvasive technique for detection of left atrial myxomas. In addition, this technique is capable of displaying the size and motion of these tumors. When both echocardiogram and gated blood pool scan are positive, we would consider this information sufficient to proceed directly to surgery without angiographic study. The gated scan would be particularly useful in evaluating patients in whom an adequate echocardiogram is not obtainable.

**FIGURE 4.** Unprocessed and computer processed diastolic, right anterior oblique gated radionuclide cardiac images in a patient (R.A.) with a large left atrial myxoma. A blood pool defect (see arrow) is clearly defined in the region of the left ventricle in the computer processed image on the right. This defect is poorly defined in the unprocessed image on the left.
Hypertrophic Cardiomyopathy

Evaluation by Gated Cardiac Blood Pool Scanning

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SUMMARY The gated radionuclide cardiac blood pool scan (GCS) can be used to visualize the entire profile of the interventricular septum and left ventricular contraction. Twenty-two patients with hypertrophic cardiomyopathy, nine with valvular aortic stenosis and six normals, underwent echocardiography and GCS. All patients with hypertrophic cardiomyopathy had asymmetric septal hypertrophy and 14 of 22 had resting systolic anterior motion of the anterior leaflet of the mitral valve on echocardiogram. In eight patients with aortic stenosis with adequate echocardiograms, two had asymmetric septal hypertrophy and none had systolic anterior motion. The GCS demonstrated disproportionate upper septal thickening in 11; septal flattening in 16; cavity obliteration in 17; and a filling defect in the region of the left ventricular outflow tract in 16 of the 22 patients with hypertrophic cardiomyopathy. In the nine patients with valvular aortic stenosis, two demonstrated septal flattening, two cavity obliteration, two an outflow tract defect, and none disproportionate upper septal thickening. Both patients with cavity obliteration demonstrated asymmetric septal hypertrophy on echocardiogram. One normal control patient had septal flattening.

Thus the gated cardiac blood pool scan provides an atraumatic technique for the evaluation of patients with hypertrophic cardiomyopathy which complements the echocardiogram.

METHODS

Gated scans were performed with a Searle HP-Pho Gamma III Anger camera positioned over the patient to obtain a 30° right anterior oblique, and multiple left anterior oblique images of the heart. Twenty mCi of technetium-99m electrolytically bound to human serum albumin were injected via an antecubital vein. Several minutes were allowed for equilibration within the blood pool. A physiological synchronizer* allowed for collection of counts gated with the electrocardiogram for 60–80 msec from the onset of the QRS complex (to obtain end-diastolic images) and from the peak of the T wave (to obtain end-systolic images). Approximately 400,000 counts were accumulated in seven minutes for each end-systolic and end-diastolic image pair and stored in the memory of a PDP-9 computer. Images were displayed on a cathode ray tube and polaroid photographs taken for evaluation. Images were subsequently processed using the Numedics system.† Figure 1 schematically illustrates the system used, the position of the gates and an

* Brattle Instruments, Cambridge, Mass.
† Digital Equipment Company.

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