The contribution of magnetic resonance imaging to the evaluation of intracardiac tumors diagnosed by echocardiography

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ABSTRACT Magnetic resonance (MR) imaging was performed in 14 patients with intracavitary cardiac tumors diagnosed by echocardiography. Except in the patients whose echocardiograms were diagnostic of atrial myxomas, this modality contributed important additional anatomic information regarding the tumor’s relationship to the normal intracardiac structures and/or its extension to the adjacent vascular and mediastinal structures. The MR findings correlated extremely well with the findings in all 12 patients who underwent surgical exploration or postmortem examination, and in the other two patients, MR guided the decision to obtain transvenous biopsy samples of their right heart masses.


SINCE the characterization of left atrial myxoma by M mode echocardiography as a mobile echogenic density entering the mitral valve orifice in diastole, cardiac ultrasound has been the technique of choice for the evaluation of intracardiac tumors.1 The introduction of two-dimensional echocardiography clarified the characteristic relationship of this tumor to the interatrial septum,2 and this ultrasonic imaging modality has provided excellent detail of the origin and extent of other intracavitary tumors arising from and limited to the heart.3,4

Magnetic resonance (MR) imaging is a newer technique that enables high-resolution tomography in three dimensions. It is nonionizing, and generates intravascular and soft tissue contrast without the need for contrast medium. In the last few years, this modality has become available clinically for noninvasive body imaging. More recently, electrocardiographic gating has made possible the high-resolution depiction of cardiac morphology, making magnetic resonance a promising technique in the evaluation of cardiac neoplasms.5

While the most common cardiac tumor, left atrial myxoma, is ordinarily exclusively intracavitary, other tumors may have an extracavitary origin or extension, and may not be visualized in their entirety by standard M mode or two-dimensional echocardiography. We therefore assessed the contribution of MR imaging to the diagnostic evaluation of intracardiac tumors initially detected by echocardiography.

Materials and methods

Between 1984 and 1987, 14 patients whose intracavitary tumors were detected by echocardiography underwent magnetic resonance imaging. This group included eight men and seven women from 16 years to 74 years of age who were referred to the echocardiography laboratory for the clinical indications that are listed in table 1.

M mode echocardiograms and two-dimensional images were obtained in the parasternal long-axis, parasternal short-axis, and apical four-chamber views with the use of ATL MK600, and/or Toshiba SSH-65A, commercially available equipment. When the standard views demonstrated an intracavitary mass, attempts were made by use of subxiphoid, suprasternal, and other less standard views to image the entire extent of the tumor, as well as the great arteries, venae cavae, and pulmonary veins.

Patients whose masses had the characteristics of thrombus — arising from the mural surface of a left ventricular segmental wall motion abnormality, a globally myopathic left ventricle, or an enlarged or fibrillating left atrium with concomitant mitral valve disease6,7—were not included in this study.

The MR studies were performed in the 14 patients with a Phillips Gyroscan S5 0.5 tesla superconducting system or a Technicare 0.15 tesla resistive magnetic imager in the spin-echo mode. The studies were electrocardiographically gated, and all patients in the study were in sinus rhythm without significant ectopy.

All 14 patients included in this study had anatomic confirmation and histopathologic diagnosis of their tumor masses by
surgical resection, percutaneous transvenous biopsy, or post-mortem examination.

Results

Noninvasive imaging studies. Table 1 summarizes the clinical indications for echocardiography, as well as the M mode and two-dimensional echocardiographic findings, MR findings, and pathologic findings in each of the 14 patients.

Echocardiography was considered optimal in 10 patients and suboptimal in four patients. It detected tumor in the left atrium in six patients, in the right atrium in four patients, in the right ventricle in two patients, in the right ventricle and left ventricle in one patient, and in the right atrium and right ventricle in one patient.

Four patients (patients 10, 11, 13, and 14) had mobile masses limited to one of the two atria, with attachment to the interatrial septum and movement into the atrioventricular valve orifice in diastole. These tumors were therefore diagnosed as atrial myxomas on the basis of their echocardiographic appearance.

Cardiac MR imaging was optimal in 13 of the 14 patients referred for further evaluation of their echocardiographically detected tumors. It was suboptimal in only one patient (patient 6) who was short of breath, tachycardic, and restless.

In each of the 14 patients with an echocardiographically detected tumor, MR also demonstrated a mass, and confirmed its location as observed by echocardiography. Only in the four patients whose echocardiograms were believed to be diagnostic of atrial myxomas did MR imaging contribute no additional anatomic information about the pathologic finding.

On the other hand, MR imaging proved particularly useful in the four patients with suboptimal echocardiograms (patients 1, 2, 9, and 12). It provided high-resolution anatomic detail that confirmed the presence of the echocardiographically less well defined masses and clarified their extent and relationship to the normal cardiac structures.

Relationship to normal structures. In patient 12, MR visualization of the connection of the mass to the interatrial septum provided sufficient information to make the diagnosis of left atrial myxoma. In patient 8, whose echocardiogram had demonstrated an elongated mobile right atrial mass that was thought to be attached to the interatrial septum, MR clearly demonstrated the true origin to be at the superior aspect of the right atrial-inferior vena caval junction, thus making the diagnosis of myxoma less likely. In the two patients in whom echocardiography had demonstrated small mobile ventricular masses (patients 1 and 7), MR showed the origin of the tumors to be from the interventricular septum.

Extent of tumor. In two patients with intracavitary right atrial masses clearly visualized by echocardiography, the extracardiac origin of the tumors and their intravascular extension into the right atrium were shown only by MR, despite attempts to image the venae cavae by echocardiography. In patient 3, whose echocardiogram showed a large sessile right atrial mass (figure 1), MR not only confirmed a heterogeneous mass within the right atrium extending to and filling the superior vena cava and other thoracic systemic venous channels, but seemingly excluded extravascular mediastinal involvement (figure 2). On the other hand, while the MR findings in patient 4 confirmed the bilobular character of the intra-atrial mass imaged ultrasonically (figure 3), it also demonstrated a mediastinal mass exterior to the heart and vascular tree, penetrating the superior vena cava and extending into the right atrium (figure 4). Of note, noncontrast computerized axial tomography of the chest of this patient had demonstrated the extracardiac soft tissue mass and facilitated the visualization of calcification within it, but failed to distinguish the intravascular or intracardiac tumor mass from the blood pool (figure 5).

In the only patient with a suboptimal cardiac MR study whose echocardiogram had been satisfactory (patient 6), thoracic and abdominal MR nevertheless clarified the origin of the tumor from the right kidney, and its extension through the renal vein and inferior vena cava into the right atrium.

![FIGURE 1. Apical four-chamber echocardiogram from patient 3 showing a large sessile tumor mass (TU) in the right atrium. LA = left atrium; LV = left ventricle; RV = right ventricle; arrows = tricuspid valve leaflets.](image-url)
TABLE 1
Clinical data and noninvasive and pathologic observations in patients with intracardiac tumors

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Sex/Age (yr)</th>
<th>History and clinical indication for study</th>
<th>Echocardiographic findings</th>
<th>MR findings</th>
<th>Pathologic findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F/67</td>
<td>Atypical chest pain</td>
<td>Technically suboptimal; small mobile mass in LV outflow tract</td>
<td>Small (1 x 1 cm) mass in LV outflow tract attached to IVS</td>
<td>Surgery: Small (1 x 1 cm) LV myxoma attached to IVS</td>
</tr>
<tr>
<td>2</td>
<td>M/64</td>
<td>Progressive dyspnea, malignant melanoma excised from back 1 year earlier</td>
<td>Technically suboptimal; large RV mass, vague LV density</td>
<td>Large RV mass extending into PA, large LV mass</td>
<td>Biopsy of RV mass: Malignant melanoma</td>
</tr>
<tr>
<td>3</td>
<td>F/29</td>
<td>Pregnancy, superior vena cava syndrome</td>
<td>Large (4 cm) sessile RA mass; SVC not visualized</td>
<td>Large (6 cm) RA mass extending to SVC, subclavian V, innominate V and their branches, no extravascular mass</td>
<td>Surgery: Angiosarcoma in the RA, SVC, subclavian V, innominate V and their branches</td>
</tr>
<tr>
<td>4</td>
<td>F/73</td>
<td>Dyspnea</td>
<td>Two round mobile RA masses; SVC not visualized</td>
<td>Mediastinal mass extending into SVC and RA</td>
<td>Autopsy: Malignant thymoma penetrating the SVC and extending into RA</td>
</tr>
<tr>
<td>5</td>
<td>M/27</td>
<td>AIDS, dyspnea, hypotension</td>
<td>Large sessile RA mass, extracardiac mass compressing right atrioventricular groove</td>
<td>Large mass in LA, RV and RA extending to SVC and infiltrating entire mediastinum with compression of right PA and PVs</td>
<td>Biopsy of RA mass: Small cell lymphoma</td>
</tr>
<tr>
<td>6</td>
<td>M/56</td>
<td>Hematuria, fever, dyspnea, systolic murmur</td>
<td>Large mass in RA and RV; IVC not well visualized</td>
<td>Mass in right kidney extending to renal V, IVC, RA, and RV; heart poorly visualized</td>
<td>Surgery: Hypernephroma in right kidney extending via right renal V into IVC and to RA and RV</td>
</tr>
<tr>
<td>7</td>
<td>M/16</td>
<td>Systolic murmur, previous echo: MV prolapse</td>
<td>Mobile 1 x 1.5 cm mass in RV inflow tract at base of septal TV leaflet</td>
<td>1 x 1.5 cm mass connected to RV side of IVS</td>
<td>Surgery: Small RV myxoma</td>
</tr>
<tr>
<td>8</td>
<td>F/34</td>
<td>Chronic renal failure (receiving hemodialysis), increase in cardiothoracic ratio on chest x-ray</td>
<td>Partially mobile 2 x 4 cm RA mass ? attached to IAS; IVC not visualized</td>
<td>2 x 5 cm RA mass attached to superior aspect of IVC junction</td>
<td>Surgery: Large partially calcified RA thrombus attached to superior or junction of SVC</td>
</tr>
<tr>
<td>9</td>
<td>M/60</td>
<td>Carcinoma of lung, ? pericardial effusion</td>
<td>Technically suboptimal; pericardial effusion, vague LA mass; PV not visualized</td>
<td>Pericardial effusion, left lung mass extending to PV and LA</td>
<td>Autopsy: Oat cell carcinoma extending to PVs and LA</td>
</tr>
<tr>
<td>10</td>
<td>M/62</td>
<td>Diastolic murmur</td>
<td>Mobile LA mass entering MV orifice in diastole, connected to IAS</td>
<td>LA mass connected to IAS</td>
<td>Surgery: LA myxoma</td>
</tr>
<tr>
<td>11</td>
<td>F/39</td>
<td>Murmur, fever</td>
<td>Mobile LA mass entering MV orifice in diastole, connected to IAS</td>
<td>LA mass connected to IAS</td>
<td>Surgery: LA myxoma</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>Murmur, dyspnea</td>
<td>Technically suboptimal; large (4 x 4 cm) LA mass entering MV orifice in diastole; mural connection not visualized</td>
<td>Large LA mass connected to IAS</td>
<td>Surgery: LA myxoma</td>
</tr>
</tbody>
</table>
### TABLE 1
(Continued)

<table>
<thead>
<tr>
<th>Patient No.</th>
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<th>MR findings</th>
<th>Pathologic findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>F/52</td>
<td>Systemic emboli</td>
<td>Mobile LA mass entering MV orifice in diastole, connected to IAS</td>
<td>LA mass connected to IAS</td>
<td>Surgery: LA myxoma</td>
</tr>
<tr>
<td>14</td>
<td>M/74</td>
<td>Murmur</td>
<td>Mobile RA mass entering TV orifice in diastole, connected to IAS</td>
<td>RA mass connected to IAS</td>
<td>Surgery: RA myxoma</td>
</tr>
</tbody>
</table>

A = artery; IAS = interatrial septum; IVC = inferior vena cava; IVS = interventricular septum; LA = left atrium; LV = left ventricle; MV = mitral valve; PA = pulmonary artery; PV = pulmonary vein; RA = right atrium; RV = right ventricle; SVC = superior vena cava; TV = tricuspid valve; V = vein.

**FIGURE 2.** MR tomograms from the same patient as in figure 1 demonstrating the intravenous extension of the tumor (TU). A, Axial image through the atria showing a heterogeneous high signal tumor mass within the right atrium (arrows). D = descending aorta; LA = left atrium; RVO = right ventricular outflow tract. B, Axial image at the level of the upper aortic arch (A) and great vessels showing tumor mass within the superior vena cava (arrows) and brachiocephalic vein (BCV). C = left carotid artery; I = innominate artery; T = trachea. C, Sagittal image showing the tumor mass within the right atrium (RA), extending into and filling the superior vena cava (SVC). IVC = inferior vena cava.
MR imaging in three other patients elucidated the more extensive vascular, intracardiac, and extracardiac nature of their tumors. In one patient with a suboptimal echocardiogram (patient 2), the right ventricular mass visualized by echocardiography was noted by MR to extend into the pulmonary artery, and more definitively to fill the left ventricle. In another (patient 5), MR imaging of the mediastinum confirmed the tumor’s extensive infiltration into the heart and the superior vena cava, as well as its compressive effects on the pulmonary veins and right pulmonary artery. Finally, in one patient with a technically suboptimal echocardiogram that showed only a pericardial effusion and vague left atrial mass (patient 9), a left lung mass with infiltration of the pulmonary vein and left atrium were defined by MR imaging.

In summary, MR imaging did not add information in four patients, but provided significant delineation of the anatomic relationship to normal structures and/or tumor extent in 10 patients.

Pathologic correlates. All of the 14 patients who underwent diagnostic evaluation of their tumor masses by echocardiography and MR imaging had anatomic confirmation of their noninvasively diagnosed masses: 10 by surgical exploration and resection, two by percutaneous transvenous biopsy of their right heart tumor masses, and two at postmortem examination.

Surgical findings. All five patients whose noninvasive studies (echocardiograms and/or MR) were thought to be diagnostic of atrial myxoma had myxomas removed at surgery and there were no additional anatomic findings. In addition, two patients whose ventricular masses were demonstrated by MR to be attached to the septum (patients 1 and 7) had operative resection of myxomas that were confirmed to have their origins at the interventricular septum.

In one patient (No. 8) who had renal failure requiring hemodialysis, a large partially calcified mass was removed from the right atrium. Histopathologic examination revealed it to be a calcified thrombus, rather than a neoplastic mass. Although initially considered a myxoma because of the echocardiographic findings, demonstration by MR of its true origin (from the inferior vena cava rather than the interatrial septum) had raised doubts about the ultrasound diagnosis.

Confirmation of the noninvasive anatomic findings was obtained at surgery in two other patients. In patient 6, whose abdominal and thoracic MR study had clearly delineated an intravascular tumor pathway from the right kidney to the heart, surgical exploration confirmed a hypernephroma extending to the right atrium and ventricle through the inferior vena cava. Patient 3, whose MR study had demonstrated only intravascular and intracardiac tumor, suggesting an endothelial origin of the neoplasm, was found to have angiosarcoma in the right atrium, superior vena cava, and subclavian and innominate veins and their branches, and no angiosarcoma outside the intravascular space.

Transvenous biopsy findings. Two patients underwent transvenous biopsies of their right heart masses.

FIGURE 3. Modified subxiphoid echocardiogram from patient 4 demonstrating two round tumor masses (M) in the right atrium. L = liver; LA = left atrium.
(patients 2 and 5). In each of these two moribund patients, this approach to diagnosis was guided by the noninvasive findings, particularly MR confirmation of large sessile tumors in the right heart. In the patient with AIDS (No. 5), whose superior vena cava could not be visualized ultrasonically, MR imaging showed tumor extending into the superior vena cava. Based on this finding, the routine approach to biopsy through the superior vena cava was deemed risky, and biopsy of the right atrial mass was therefore performed via percutaneous cannulation of the femoral vein and right atrial entry through the inferior vena cava.

In both cases, adequate tissue samples were obtained without complication. Histologic diagnoses of small cell lymphoma and malignant melanoma were made respectively in these two patients. Both patients died within 48 hr of the biopsy, and neither had a postmortem examination.

**Autopsy findings.** Postmortem examinations were performed in two patients (Nos. 4 and 9), and confirmed the noninvasive anatomic findings of extensive tumor infiltration of the mediastinum in both. Cardiac histologic examination confirmed malignant thymoma and oat cell carcinoma, respectively.

In summary, of the 11 subjects who were explored either surgically (nine patients) or at postmortem examination (two patients), MR imaging was as predictive as echocardiography in the four patients with the ultra-
sound diagnosis of atrial myxoma, and provided additional anatomic information ultimately confirmed by exploration in the seven remaining patients. In two other cases, the MR findings contributed to the decision to obtain transvenous biopsy samples from the right heart masses, and was particularly useful in guiding the venous approach.

Discussion

While echocardiography—which is widely available, at the bedside as well as in the laboratory, noninvasive and harmless, not time consuming, and relatively inexpensive—remains the technique of choice in the initial evaluation of intracardiac tumors, MR imaging proved an important adjunct in the diagnostic evaluation of many echocardiographically detected tumors.

Bone and lung interference remains a major limitation of echocardiography, and in the adult population, in particular, not infrequently renders this realtime imaging technique suboptimal in patients with chronic obstructive pulmonary disease or narrow rib spaces. In addition, ultrasonic cardiac imaging requires an approach through limited windows, not all of which are accessible in patients whose obesity, other body habitus abnormality, or inability to lie in specific positions precludes imaging through these isolated windows.

On the other hand, MR—an evolving modality that requires a more sophisticated technology that is more personnel intensive, more expensive, and less widely available—can provide excellent nonreal-time digitally reconstructed images, even in patients in whom echocardiography is difficult or impossible. MR uses a technology that at present cannot be brought to the bedside and requires longer acquisition time, thus necessitating that patients be transported and be able to lie supine (either on their own, sedated, or anesthetized). Additionally, electrocardiographic gating mandates that patients have regular cardiac rhythms, and because this modality involves a strong magnetic field, it cannot be used to assess acutely ill patients requiring ferromagnetic support systems such as respirators, monitors, pacemakers, and catheter needles. 10

Given the limited time resolution of the technology that is currently in clinical use, MR cannot be used to assess valve motion, and ultrasonic and nuclear-gated blood pool scanning remain superior techniques for evaluation of dynamic cardiac function. In addition, because calcium cannot be identified by MR, when calcification of a mass or other mediastinal structure is at issue, ionizing imaging techniques such as computerized axial tomography offer a distinct advantage.

Nonetheless, in patients who can be studied by MR, this nonionizing, noncontrast-requiring tomographic

FIGURE 5. Noncontrast computerized axial tomogram (approximately cut of figure 4, B) showing the anterior mediastinal mass (M) containing calcification (black arrow) outside the heart and vascular structures. Pleural effusion or tumor (white arrow) is also seen, but tumor cannot be distinguished from the intracardiac or intravascular blood pool. A = ascending aorta; D = descending aorta; LA = left atrium; LV = left ventricle; RV = right ventricle; SVC = superior vena cava.
technique yields images of the entire thorax, including the mediastinum, lungs, and great vessels, which in our series represented a significant advantage over echocardiography in the assessment of intracavitary tumors. In their early series of 10 patients whose paracardiac masses were studied by MR, Amparo et al. concluded that this modality was as good as echocardiography, computerized axial tomography and angiography combined in the evaluation of intramural, pericardial and mediastinal cysts, tumors and thrombi.

In this study, results of MR imaging correlated extremely well with the exploratory anatomic findings and, except in the four patients with atrial myxoma diagnosed by echocardiography, provided important additional anatomic information that could not be obtained by echocardiography. MR was therefore superior to echocardiography in the noninvasive evaluation of these intracavitary tumors. In most of the cases described, MR imaging allowed better delineation of the relationship of intracavitary masses to the normal structures, including the tumor's site of mural attachment and its extension to both the great vessels and adjacent extracardiac mediastinal structures. MR also yielded excellent images in cases in which echocardiography was suboptimal.

We recommend that in adult patients, unless technically adequate echocardiography demonstrates an exclusively intracavitary atrial mass characteristic of myxoma, the origin and extent of a visualized tumor mass be explored by MR imaging. Computerized axial tomography is an alternative, especially given the newer ultrafast cine technology that enables imaging of the heart in motion. This technique, however, is not entirely noninvasive because it requires the use of ionizing radiation and, not infrequently for the imaging of cardiovascular structures, an intravascular injection of contrast medium.

While in many cases the origin and extent of tumor by either tomographic technique may suggest the pathologic diagnosis, accurate histologic diagnosis is not presently available by noninvasive means. Tissue characterization, however, has become a major field of interest, and in this respect, MR imaging is particularly promising.

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The contribution of magnetic resonance imaging to the evaluation of intracardiac tumors diagnosed by echocardiography.
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