MR Imaging of Mitral Stenosis

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Index Words: Mitral valve, stenosis 534.172
Heart, MR studies
Heart, thrombosis

Introduction

For the pathoanatomical assessment of mitral stenosis(MS), various diagnostic modalities such as plain chest radiography, echocardiography, cardiac catheterization and cine–cardiography have been used[1,2]. Each modality has its own advantages and disadvantages and these modalities are not satisfactory to visualize every cardiac chamber including left atrial cavity and appendage where thrombosis frequently occurs.

For treatment of mitral stenosis, interventional procedures such as percutaneous balloon valvuloplasty were developed recently in addition to
surgical mitral commissurotomy or mitral valve replacement. To perform these surgical or nonsurgical procedures adequately without complication, accurate pre-operative delineation of every cardiac structure, especially left atrium (LA), is necessary.

Cardiac MR imaging has become an effective modality for the evaluation of congenital and acquired heart diseases. Authors performed cardiac MR imaging in 41 patients with MS to analyse the MR findings prospectively and to correlate the findings with the hemodynamic results of cardiac catheterization.

Materials & Methods

Spin-echo MR imaging was performed in 41 patients with MS from April 1988 to March 1989. Male was 11 and female was 30. Age range was from 17 to 70 years (mean age: 37.2 years). The most frequent chief complaint was dyspnea on exertion in 36 patients (89%). Functional class of the patients was NYHA class I to III in 39 patients (95%). Patients with mitral stenosis combined with regurgitation more than grade I/IV and patients of combined aortic valvular disease were excluded. Spin-echo MR imaging was performed in 15 normal adult volunteers to measure the size of normal LA. Males were 10 and females were 5. Age range was from 20 to 47 years old (mean age: 31.3 years).

The diagnosis of MS suggested with clinical findings, plain chest radiography and echocardiography prior to MR imaging. On ECG, atrial fibrillation was demonstrated in 14 cases (34%). In 19 patients, ECG revealed findings of left atrial enlargement and right ventricular hypertrophy. Three to seven days after MR imaging, cardiac catheterization and left ventriculography were done in all cases except one with cine-cardiographic x-ray unit (Poly Diagnost C, Philips Co). During the catheterization, pressure and O₂ saturation were measured for pulmonary artery wedge, pulmonary artery, right ventricle, left ventricle and aorta.

After these evaluations, percutaneous double balloon valvuloplasty was done in 23 patients successfully. Open-heart surgery for mitral valve replacement was done in 11 patients. In these patients, rheumatic valvulitis was pathologically confirmed for the stenotic mitral valves.

Transverse, coronal and oblique views of ECG gated MR imaging were obtained with 2.0T MRI system (Spectro-20000, Gold Star, Seoul, Korea). The oblique view was taken with variable angles along the long axis of the heart parallel to the axis of interventricular septum of the transverse image in each patient. In transverse view, multislice double spin-echo imagings were also performed in all patients with echo delay time (TE) of 30 msec and 60 msec, triggering at every other beat. The imaging matrix was 180x256 elements, and the pixel size was 1.5x1.5 mm. The multislice imaging was done from top of the aortic arch to diaphragm with 8 mm section slice thickness and 2 mm gap. One to two transverse images of pulmonary artery were taken at systolic cardiac phase. Three to four transverse sections of the left atrium were also taken at 320 to 640 msec after R-wave, the corresponding cardiac phase of ventricular diastole.

The MR findings of MS were analysed prospectively by two cardiac radiologists and correlated with the hemodynamic data. On the transverse view of the cardiac MR imaging, transverse and anteroposterior diameters of LA were measured at the level of aortic root (Fig. 1). The transverse diameter of LA was defined as the longest transverse distance between both lateral sides of the left atrium at the level of aortic root. The anteroposterior diameter was defined as the distance of LA between ascending aorta and descending aorta, perpendicular to the transverse diameter at the same level. The diameters of LA in patients with MS were compared with those of normal volunteers and statistical examination was done with T-test. Relative signal intensity of the left atrium was observed comparing with the signals of muscles and they were divided into three groups with gross subjective estimation by
the two radiologists: (group I) signal void, (group II) flow–related high signal occupying less than a half space of LA, and (group III) high signal occupying more than a half of LA. The MR findings were correlated with wedge pulmonary arterial pressure. Flow–related signals of pulmonary artery were also observed in the transverse image of cardiac systolic phase and correlated with systolic pulmonary arterial pressure. Interventricular septum was observed whether it showed convexity toward right atrium, deviated more than 5 mm from original flat position. The curvature of interventricular septum was also observed subjectively. Mitral valve was observed at the atrioventricular level in the transverse and oblique views. Statistical evaluation for the correlation of MR findings with hemodynamic data was done using Kruskal–Wallis test.

Results

ECG gated cardiac MR images delineated every cardiac chamber in 15 normal adults and all patients of MS except three patients with severe atrial fibrillation. In those three patients the contours of both ventricles and interventricular septa were blurred due to poor acquisition. However, left atria could be identified and were of similar quality with those of the patients without atrial fibrillation. The transverse and anteroposterior diameters of LA were significantly enlarged in patients with MS. The results of size measurement of LA were summarized in Table 1.

No flow related signal was detected in the LA of 15 normal volunteers at ventricular diastolic phase. However, in the enlarged LA and appendage due to MS, variable degree of inhomogeneous intraluminal signals were demonstrated in diastolic phases of cardiac cycle in 32 patients (78%). The flow–related signals were detected in the left atrial cavity of the transverse, coronal and oblique views. In six patients of them, the flow–related signals occupied more than half space of left atrial cavity (group III). In these cases homogeneous signals occupied whole space of LA except pulmonary venous inflow areas(Fig. 2). In the 26 cases who had mild degree of flow–related signals less than half space of LA (group II), the frequent sites of flow signals were left atrial appendage (24 cases), near junctional area of atrial appendage (13 cases), atrial base (13 cases), septal side (8 cases), and atrial roof (8 cases). The left atrial appendage showed homogeneous or inhomogeneous flow–rela-

Table 1. Transverse and Anteroposterior Diameters of Left Atrium in Transverse Images of 15 Normal Volunteers and 41 Patients with Mitral Stenosis.

<table>
<thead>
<tr>
<th></th>
<th>Transverse</th>
<th></th>
<th>Anteroposterior</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range (cm)</td>
<td>Mean ± SD (cm)</td>
<td>Large LA (&gt;7.7 cm)</td>
<td>Range (cm)</td>
</tr>
<tr>
<td>Normal</td>
<td>15</td>
<td>6.0–8.2</td>
<td>7.0 ± 0.7</td>
<td>4 / 15 (27%)</td>
</tr>
<tr>
<td>MS'</td>
<td>41</td>
<td>6.3–13.2</td>
<td>8.9 ± 1.4</td>
<td>36 / 41 (88%)</td>
</tr>
</tbody>
</table>

* The diameters in MS were significantly larger (P < 0.001) with T–test.
ted signals in the transverse view of 35 patients (85%). In three cases, only appendage revealed flow-related signals (Fig. 3). In the second echo images, the flow-related signals of the LA and appendage increased in relative signal intensity and extent in 31 cases (91%) (Fig. 3).

Mean wedge pulmonary arterial pressure was measured with Swan-Ganz catheter during right heart catheterization and it was ranged from 7 to 55 mmHg (Mean ± SD: 20.4 ± 10.5 mmHg). In 21 patients with wedge pressure higher than 20 mmHg, 20 patients (95%) showed flow-related signals in the LA. The MR findings of intraluminal signal in LA in first echo image were correlated with wedge pulmonary arterial

![Fig. 2. Double echo MR imaging of mitral stenosis. Flow-related signals are noted in left atrium.

a. The first echo image (TE: 30 msec) shows inhomogeneous flow-related signals in the enlarged left atrium.

b. In second echo image, the flow-related signals in left atrium are enhanced homogeneously except small round defects (small arrows) due to pulmonary venous inflows.

c. Fig. 3. Transverse and coronal views of left atrial appendage in mitral stenosis.

a. In the first echo image, flow-related signals are found in the appendage (arrow).

b. In the second echo image, the signals in the appendage are (arrow) enhanced homogeneously. The filling defect at the posterior portion of atrial appendage is due to left upper pulmonary venous inflow.

c. In the coronal view of first echo image, the left atrial appendage (arrow) shows no intraluminal signals, suggesting absence of thrombus.
pressure in 40 patients (Fig. 4). According to the Kruskal–Wallis test, the three groups showed significantly different wedge pulmonary arterial pressures ($P < 0.05$).

Left atrial thrombus was observed in 3 cases, which was proved by surgery in all cases. The sites of atrial thrombus were appendage and left upper side of the cavity in two cases and posterior wall in one case. In the first echo image, the thrombus was identified as a high intensity inhomogeneous mass with low intensity rim surrounded by inhomogeneous flow–related signals in two cases. The thrombi were higher intensity than the myocardium or flow–related signals in first echo images. In the second echo images, the relative intensity of the flow–related signals increased while that of the thrombi was not changed or decreased (Fig. 5A, B). In one case, the thrombus at posterior wall was inhomogeneous high intensity not well separated from surrounding flow–related signals in first echo image. Second echo image, however, showed medium intensity mass clearly contrasted by surrounding enhanced flow–related signals.

None of the normal adults showed flow–related signals within pulmonary artery on transverse view in systolic phase. However, in 9 cases (22%) of MS, flow–related signals were detected within pulmonary artery on transverse view in systolic cardiac phase (Fig. 6). In seven of them, the systolic pulmonary arterial pressure was higher than 50 mmHg. The flow–related signals of the pulmonary artery were also enhanced in the second echo images in all cases.

Though mitral valve could not be identified in diastolic phase of normal adults, diastolic doming of the stenotic mitral valve with variable

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**Fig. 4.** Hemodynamic correlation of intraluminal signal in LA in first echo transverse MR image in 40 patients of MS. Group I: signal void in LA, Group II: intraluminal flow–related signal occupying less than a half of LA, Group III: flow–related signal occupying more than a half of LA. Individual wedge pulmonary arterial pressure was plotted with dot. Mean and standard deviation (SD) in each group were also plotted with lines.
Fig. 6. MR findings of mitral stenosis. Flow-related signals in right pulmonary artery (arrow) of systolic phase due to pulmonary hypertension.

Fig. 7. Thickened mitral valve with dome shape (arrow) is demonstrated in the diastolic phase, while the tricuspid valve is not identified.

thickness was seen in 39 cases (95%) in transverse and oblique views (Fig. 7). Interventricular septum at the level of aortic root showed convexity toward the right atrium in 26 cases (63%) (Fig. 6, 7). Interventricular septum was flat in 22 cases and reversed with convexity toward left ventricle in 2 cases (Fig. 6).

Associated lesions were also demonstrated in multiplanar images. Pulmonary infarct was detected in three cases (Fig. 8). Pleural effusion was noted in two patients (Fig. 5), and pulmonary infarction was associated in one patient.

Discussion

Cardiac MR imaging was known to be helpful in the diagnosis of congenital and acquired heart diseases by delineating every cardiac chamber accurately. Hill et al. described MR findings of MS in five patients. They pointed out easy visualization of mitral valve, large LA, bulging of interatrial septum, and increased signal in LA during ventricular diastole. It was known that intraluminal signals were often present during ventricular systole in LA even in healthy subjects. VonSchulthess et al. reported that 60% of healthy subjects showed signal in late systole and the signal usually was located in the left side of the LA. In MS the intracardiac signals were detected in diastolic phases of cardiac cycle in 78% of our series. The intracardiac signals of the LA were also seen in MR imaging of restrictive cardiomyopathy. It is widely accepted that these flow-related signals were induced by slow flow. In our cases of tight MS with mean wedge pulmonary arterial pressure more than 20 mmHg, 95% showed intraluminal signals in the LA. The incidence and extent of the intraluminal signal in LA increased with high wedge pulmonary arterial pressure on the basis of our correlative evaluation. However, it was difficult to establish linear relationship of the pulmonary arterial wedge pressure directly with the flow-related signal intensity of left atrium. Flow related signals were also noted in some cases of relatively low LA pressure. There must be other minor factors influencing the flow-related signals such as compliance of LA
and volume of left atrium.

Most thrombi in mitral valve disease are small and occur frequently within the left atrial appendage. The pre-operative diagnosis of left atrial thrombus in MS is important to choose treatment method1,2,10,11. In cases of left atrial thrombus, percutaneous mitral balloon valvuloplasty is contraindicated. Presence of thrombus influences the choice of surgical technique and the operative risk1,2. Two-D echocardiography demonstrated only one-third of confirmed thrombi and the clots in the appendage were frequently missed by ultrasound1,10. CT evaluation was also reported to be an accurate method to identify the intracardiac thrombus. However, its clinical use is not widely accepted yet because of the low contrast of soft tissue and motion artifact. Cardiac thrombi were reported usually to have higher signal intensity than the normal myocardium on MR imaging, especially in the second echo image11-13. However, the findings of left atrial thrombi were variable due probably to variable degree of organization and fibrotic changes of the thrombi. Small thrombus within the appendage might be obscured by the strong intraluminal flow-related signals, resulting in false negative MR imaging. The diagnostic accuracy of MR imaging for the differentiation between thrombus and slow flow in LA is yet to be investigated with further studies.

In cases with severe MS, pulmonary arterial hypertension is also associated. Flow-related signals within the pulmonary artery in systole are consistent with decreased flow velocity in patients with severe pulmonary hypertension14. In addition, associated pulmonary infarction and pleural effusion were detectable with MR imaging.

On the basis of our experience, though we had difficulty to correlate MR findings directly with hemodynamic data sufficiently to obviate catheterization, we believe that spin-echo MR imaging is a valuable diagnostic modality which provides various pathoanatomical and physiological informations in the patients with MS.

Summary

In order to study MR findings of mitral stenosis, ECG gated MR imaging was performed with a 2.0 T MR system prospectively in 41 patients of mitral stenosis before catheterization.

Mean transverse diameter of left atrium was $8.9 \pm 1.4$ cm and anteroposterior diameter $5.1 \pm 1.0$ cm, suggesting significant enlargement. Homogeneous or inhomogeneous flow-related signals at ventricular diastolic phase were detected in left atrial cavity in 32 cases(78%), and in atrial appendage in 35 cases(85%). In 21 patients with mean wedge pulmonary arterial pressure higher than 20 mmHg, 20 patients(95%) showed flow-related signals in ventricular diastolic phase. Other MR findings were mitral valve with doming in diastole, flow-related signal in pulmonary artery in systole, left atrial thrombi, etc.

REFERENCE