Advantage of Cine-MR Imaging for the Evaluation of Valvular Regurgitation

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It is well known that the regurgitant blood flow of valvular disease shows a low intensity signal (LS) in cine-MR imaging (cMRI). To determine the significance of cMRI in evaluation of valvular regurgitation, 104 patients who had been assessed by cineangiography also underwent oblique cMRI for mitral regurgitation (MR) and aortic regurgitation (AR), and transverse cMRI for tricuspid regurgitation (TR).

In evaluating the accuracy of diagnosis of valvular regurgitation on the basis of the presence of LS in the recipient chamber, sensitivity was found to be 93.5% for MR, 100% for AR and 85.7% for TR; specificity was 76.9% for MR and 100% for AR.

The length and area of LS were planimetered in any view with the largest area, and its ratios to the length and area of the recipient chamber of view were calculated. Each index was significantly higher than the degree calculated by cineangiography. The best correlation with angiography was the ratio of the area of LS to the recipient chamber, and a semiquantitative classification by the index was coincident with angiographic severity in 38 of 43 (88.4%) patients undergoing MR, and in 28 of 30 (93.3%) patients undergoing AR.

Thus, cMRI is a clinically useful noninvasive method in the identification and semiquantitative assessment of regurgitation severity.

In the diagnosis of valvular regurgitant disease, correct assessment of severity is important in the choice of appropriate treatment and in following the course of the disease. In the past, cardiovascular angiography has conventionally been used as a gold standard for assessment of the severity of valvular regurgitation. However, since this method is invasive and necessitates injection of contrast medium, its application has been limited. Doppler echocardiographic techniques, by contrast, are noninvasive, and the appearance of two-dimensional Doppler echocardiography in particular has improved the accuracy and ease of diagnosis. However, since a large number of problems remain with regard to quantitative assessment, there has been an urgent need for development of a new noninvasive methodology. The recently developed technique of cine-MR imaging shows great promise as a method of wide applicability in assessment of blood flow dynamics within the heart and vessels. On the cine-MR imaging, the regurgitant blood flow of valvular disease is known to be displayed as a low intensity signal, and comparisons of this method with the Doppler technique are being made in relation to their usefulness in the diagnosis of valvular regurgitation.

In the present study, the authors have examined the low intensity signal in cine-MR images in order to ascertain whether they were

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TABLE 1  RELATIONSHIP OF CHARACTERISTICS TO SEVERITY OF MR.

| Parameter     | Mild  
|              | (n = 21) | Moderate  
|              |          | (n = 19) | Severe  
|              |          |          | (n = 6) |
| LLS (cm)     | 3.7 ± 1.0 | 6.1 ± 1.6 | 10.0 ± 2.5 |
| ALS (cm³)    | 4.3 ± 1.8 | 13.4 ± 5.3 | 43.3 ± 22.0 |
| LLS/LLA (%)  | 51 ± 16 | 78 ± 15 | 100 ± 0 |
| ALS/ALA (%)  | 19 ± 11 | 53 ± 12 | 87 ± 11 |

Mean ± 1SD.
LLS = length of low intensity signal; ALS = area of low intensity signal; LLA = length of left atrium;
ALA = area of left atrium.
*p < 0.005

useful in diagnosis of the presence of valvular regurgitation, and in assessing its severity, by comparing the findings of these examinations with those of cineangiography.

MATERIALS AND METHODS

Study patients: The subjects covered by the study were 104 patients assessed by cineangiogram, in whom mitral regurgitation (MR) was identified in 85, aortic regurgitation (AR) in 40, and tricuspid regurgitation (TR) in 7 patients. Patients with mitral stenosis and severe MR, in whom a low intensity signal appeared in the left ventricle during the diastolic period, making assessment of the low intensity AR signal difficult, were excluded from the investigation of AR. The angiographic assessment of the severity of valvular regurgitation was divided into 3 grades by 2 diagnosticians unaware of the results of cine-MR imaging.

The equipment used in the study was a 1.5 Tesla superconductive MR imaging apparatus (Siemens, MAGNETOM). The imaging sequence involved the continuous acquisition at a repetition time (TR) of 20 to 30 msec, a gradient refocused echo time at 10 msec, with a flip angle of 30°, and a slice thickness of 7 mm. Two signal averages were performed with a 256 × 256 image acquisition matrix and a 40 cm field of view. The plane of the cine-MR imaging for evaluating AR and MR was fixed using a line joining the center of the orifice of the aortic valve and the apex on the coronal gated spin echo image, as for TR, by using a transverse line coincident with the center of the orifice of the tricuspid valve. Continuous cine matic display of the images was carried out, with the cardiac cycle divided into 31 phases by means of electrocardiogram synchronization with the R waves.

The presence or absence of a low intensity signal, and the shape and size of any such region was monitored in the left atrial blood flow MR signals, the left ventricular AR signal and the right atrial TR signals. The results of cine-MR imaging were compared with those of cineangiography to assess the advantages of cine-MR imaging in evaluation of MR, AR and TR.

RESULTS

1. Accuracy of diagnosis of valvular regurgitation.

In order to assess the usefulness of observing the presence of low intensity signals in cine-MR images as a basis for the diagnosis of valvular regurgitation, the results of this method were compared with the findings of cineangiography.

A low intensity signal extending from below the mitral valve into the left atrium during systole was seen in 43 of the 46 patients in whom MR was detected by cineangiography. Moreover, a low intensity signal was not found in 30 of the 39 subjects in whom MR had not been detected by cineangiography (sensitivity 93.5%, specificity 76.9%).
TABLE II  RELATIONSHIP OF CHARACTERISTICS TO SEVERITY OF AR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mild (n = 11)</th>
<th>Moderate (n = 11)</th>
<th>Severe (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLS (cm)</td>
<td>4.3 ± 1.0</td>
<td>7.8 ± 1.3</td>
<td>9.0 ± 1.3</td>
</tr>
<tr>
<td>ALS (cm²)</td>
<td>3.9 ± 1.7</td>
<td>17.1 ± 5.5</td>
<td>30.3 ± 6.0</td>
</tr>
<tr>
<td>LLS/LLA (%)</td>
<td>55 ± 17</td>
<td>79 ± 8</td>
<td>95 ± 8</td>
</tr>
<tr>
<td>ALS/ALA (%)</td>
<td>13 ± 6</td>
<td>37 ± 7</td>
<td>69 ± 10</td>
</tr>
</tbody>
</table>

Mean ± 1SD, LLS = length of low intensity signal; ALS = area of low intensity signal; LLV = length of left ventricle; ALV = area of left ventricle.

*p < 0.005, **p < 0.05

A low intensity signal extending from just below the aortic valve into the left ventricle during diastole was seen in all of 30 patients in whom AR had been detected by cineangiography. In the other hand, a low intensity signal was found in none of the 10 subjects in whom AR had not been detected by cardiac catheterization (sensitivity 100%, specificity 100%).

A low intensity signal extending from below the tricuspid valve into the right atrium during systole was seen in 6 of 7 patients in whom TR had been detected by cineangiography (sensitivity 85.7%).

2. Assessment of the severity of valvular regurgitation based on characteristics of the low intensity signals.

The length and area of the low intensity MR signal (LLScm and ALScm², respectively) were planimetered in any view with the largest area, and the ratio to the length of the left ventricle (LLV cm) of the same view and to its area (ALVcm²), respectively, was calculated. With AR and TR, the same measurement of the low intensity signal was made, and its ratios to the length and area of the left ventricle (LLV, ALV) and right atrium (LRA, ARA) calculated. Next, for each of these low intensity signal indices, mean values and standard deviations were derived at the 3 grades of severity determined by cineangiography.

Each index was significantly higher than the MR and AR severity calculated by cineangiography (Table I, II). With TR, there was a tendency for each index to be higher.

3. Semiquantitative classification of the severity of MR and AR.

A semiquantitative classification of the severity of MR and AR was attempted using each of the 4 just mentioned indices obtained with cine-MR imaging, and these were examined for correspondence with the categories derived by cardiac catheterization.

With regard to MR, the best correlation with angiography was the ratio of the low intensity signal area to the area of the left atrium (ALS/ALA). It classified 38 of the 43 patients (88.4%). ALS/ALA was under 40% in 18 of the 19 patients with angiographically graded mild MR, between 41% to 70% in 14 of the 18 patients with moderate MR, and over 71% in all 6 patients with severe MR. For AR, the best correlation with angiography was the ratio of the low intensity signal area to the area of the left ventricle (ALS/ALV). It classified 28 of the 30 patients (93.3%). ALS/ALV was under 25% in all 11 patients with angiographically graded mild AR, between 26% and 50% in 10 of the 11 patients with moderate AR, and over 51% in 7 of the 8 patients with severe AR. Among the patients in whom the degree of severity did not correspond when these indices used, the differences in degree were limited to a single grade, and never exceeded this.
DISCUSSION

In this study cine-MR imaging was not only highly sensitive and specific in identification of valvular regurgitation but also provided accurate estimation of its semiquantitative severity. Thus we conclude that cine-MR imaging, based on the characteristics of the low intensity signal due to regurgitant blood flow, is a clinically useful non-invasive method of evaluation of valvular regurgitation.

As for methodology, assessment by conventional cine-MR imaging is made from transverse slice images obtained at a number of levels. With the technique used in the present study, the only one slice imaging used, which was in an oblique plane in accordance with the left ventricular long axis, was carried out to assess both MR and AR. In this way we were able to reduce the time required for examination and diagnosis, and as such it was concluded that oblique cine-MR imaging provided a great advance in the usefulness of cine-MR imaging.

Comparing cine-MR imaging with the color Doppler method, one of the advantages of the former is that every examiner can get the same quality images, if the sequence parameters are uniform. In contrast, with the ultrasound Doppler technique, ultrasound transmittance through the subject's body and the skill of the examiner have a great effect on the results obtained. Another advantage of cine-MR imaging is its far better temporal resolution, since cine-MR imaging of TR every 20 msec produces a continuous image every 20 msec, whereas the color Doppler method usually operates at a frame rate of only 10 images/sec.

One of the limitations of this study is that assessment of the severity of valvular regurgitation by cineangiography, used in this study as a gold standard, is semiquantitative, and there was not always a good correlation with measurements of the regurgitant volume, as parameter considered to be the best index of the severity of valvar regurgitation. Thus, it is essential that in the future all indices of the low intensity signal studied in the present investigation, should be compared with the regurgitant volume.

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