Cine MR Imaging in Mitral Regurgitation: Comparison with Color Doppler Flow Imaging

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Cine MR imaging is a new technique that combines short repetition times, limited flip angles, gradient-refocused echoes, and cardiac gating. This procedure was performed in 20 patients in whom mitral regurgitation was shown on left ventriculography, and the results were compared with those of color Doppler flow mapping. In all cases, mitral regurgitation on cine MR imaging was depicted as an area of decreased signal intensity within the left atrium. The extent and severity of the regurgitant jet as seen by the two techniques were classified visually as 4+ (severe), 3+ (moderate), 2+ (mild), and 1+ (minimal). The results of the two methods were the same in 14 (70%) of the 20 patients. In five patients the results differed by one grade and in one patient by two grades. In addition, the maximal intrusion distance and area of the regurgitant jet divided by the area of the left atrium as determined by the two methods were compared. The correlation coefficients between the two methods in regard to the length and area of mitral regurgitation were .74 and .71, respectively.

These data suggest that the accuracy of cine MR imaging in assessing the severity of mitral regurgitation is comparable to that of color Doppler flow imaging.

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MR imaging clearly depicts cardiac anatomy in congenital and acquired heart diseases [1–3]. The technique is limited by a long imaging time and low temporal resolution. Recently, cine MR imaging techniques that use a low flip angle and gradient-refocused echoes have been developed [4–7]. They provide a series of images of the heart and great vessels at different phases of the cardiac cycles in which the velocity of flowing blood affects signal intensity. Rapid review of these images, compiled in an endless loop, results in a movie of intracardiac anatomy and flow. Thus, cine MR imaging is useful in evaluating cardiovascular function [6, 7]. A regurgitant jet is identified as a discrete area of low signal intensity extending from the incompetent valve into the respective cardiac chamber [8, 9].

In this study, we compared the extent and severity of mitral regurgitation as determined by cine MR imaging with the results obtained by real-time, two-dimensional color Doppler flow imaging.

Materials and Methods

Cine MR imaging was performed in 34 patients with mitral regurgitation who were hospitalized in the National Cardiovascular Center (Osaka, Japan) between October 1987 and March 1988. Color Doppler flow imaging and left ventriculography were performed within 2 weeks of cine MR imaging in 20 of these patients. There were 12 men and eight women 37–69 years old (mean ± SD, 54 ± 12 years). Nine patients had combined valvular heart disease, seven had dilated cardiomyopathy, two had myocardial infarction, and two had hypertensive heart disease. The severity of mitral regurgitation was confirmed by left ventriculography. According to the classification of Sellers et al. [10], seven patients had grade I, six had grade II, three had grade III, and four had grade IV regurgitation.

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MR imaging was performed by using a commercially available 1.5-T superconductive magnet (Magnetom H15, Siemens). Images were obtained by means of the FLASH (fast low-angle shot) technique, which uses the low flip angle of 30° and gradient-refocused echoes with an echo time of 16 msec. The repetition time was 30–40 msec. The data acquisition was keyed to the heart rate, with advancement of the phase-encoding gradient with the heartbeat. The acquisition matrix was 128 × 256 interpolated to 256 × 256 for display. The entire heart of each patient was imaged at a 10-mm interval by using one averaging time on the transaxial plane. All images were reconstructed at 21 frames for a cardiac cycle and displayed in a dynamic fashion (Fig. 1). Eleven frames from a 21-image/cardiac cycle sequence at the level of left atrium were assembled into a composite image. Mitral regurgitation on cine MR imaging was defined as an area of decreased signal intensity within the left atrium that originated at the valve plane and coincided with ventricular systole. The total acquisition time was approximately 45 min.

The equipment used included a real-time two-dimensional Doppler flow imaging system (Aloka XA-54 prototype with a 2.5-MHz transducer, Tokyo, Japan) and a commercially available real-time two-dimensional echocardiographic unit (Toshiba SSH-40A, 2.5 MHz transducer, Tokyo, Japan) [11, 12]. The former system allowed visualization of the topography of the intracardiac flow. The flow image was superimposed on the two-dimensional echocardiogram, which was displayed on the same screen. The latter system was used for evaluation of the morphology and dynamic features of the heart. Whether the regurgitant jet was toward the anterior or posterior atrial wall was determined in the long-axis view of the left side of the heart. The total acquisition time was approximately 30 min.

A diagram of the mitral regurgitation as depicted by cine MR imaging and color Doppler flow imaging is shown in Figure 2. The extent and severity of the regurgitant jet were classified on the basis of size as determined by visual inspection. Each technique was scored as 4+ (severe), 3+ (moderate), 2+ (mild), or +1 (minimal). The grading of cine MR imaging and color Doppler flow imaging was done independently by two observers without the knowledge of the other's finding. The maximal intrusion distance of the regurgitant jet signal from the mitral orifice into the left atrial cavity was used to determine the severity of mitral regurgitation by both techniques. In addition, the maximal area of regurgitant jet divided by the area of the left atrium was also used to determine the severity of mitral regurgitation.

Results

In all cases, mitral regurgitation on cine MR imaging was depicted as an area of decreased signal intensity within the left atrium, and the extent of regurgitant jet was compatible with that seen on color Doppler flow imaging (Figs. 3 and 4).

The severities of mitral regurgitation as determined qualitatively by cine MR imaging and color Doppler flow imaging were compared (Fig. 5). The results of the two methods were the same in 14 patients (70%) and differed by one grade in five and by two grades in one. The results of cine MR and color Doppler flow imaging were correlated with that of left ventriculography.

The maximal intrusion distance and area of the regurgitant jet signal from the mitral orifice into the left atrial cavity were determined by cine MR imaging and color Doppler flow imaging. The interobserver variabilities in cine MR imaging and color Doppler flow imaging were 0.96 and 0.94 in regard to the length and area of mitral regurgitation in 10 selected patients. The correlation coefficient between the length of the mitral jet measured by cine MR imaging and that determined by color Doppler flow imaging was .74 (Fig. 6). The lengths (mean ± SD) of the mitral jet on cine MR imaging in patients with grades I, II, III, and IV regurgitation determined by left ventriculography were 2.3 ± 0.5 cm, 5.0 ± 0.4 cm, 6.1 ± 1.9 cm, and 8.3 ± 1.6 cm, respectively. Those on color Doppler flow imaging were 1.5 ± 0.8 cm, 4.5 ± 1.0 cm, 5.7 ± 0.8 cm, and 8.2 ± 2.2 cm, respectively. In addition, the correlation coefficient between the areas of mitral jet as determined by cine MR imaging and by color Doppler flow imaging was .71

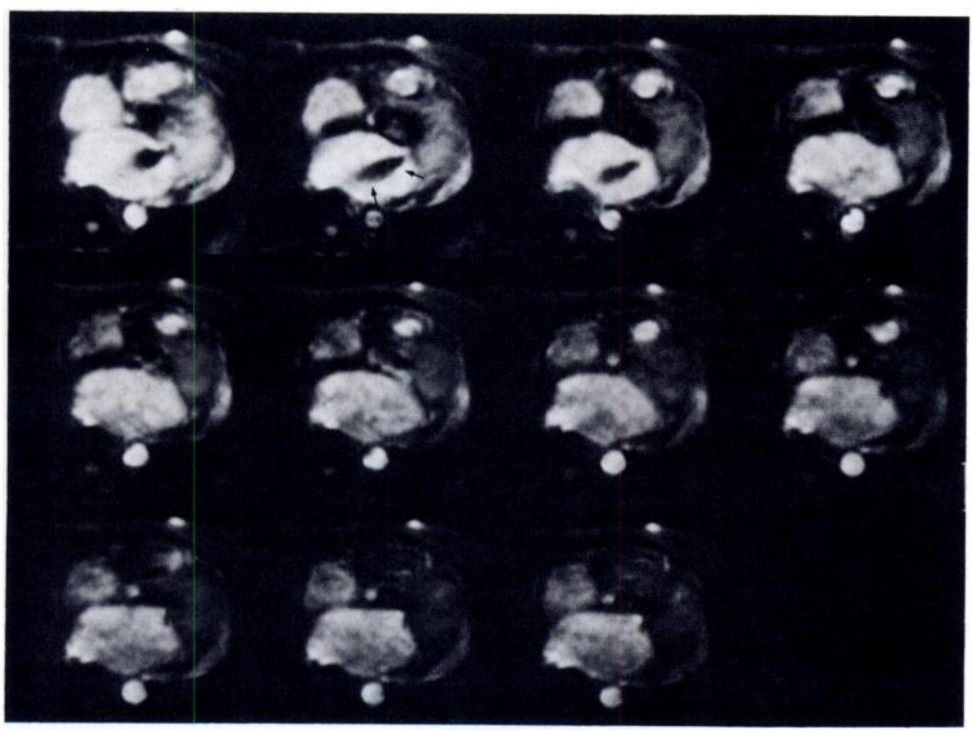


Fig. 1.—Cine MR images of mitral regurgitation at level of left atrium. A composite of 11 frames from 21-image/cardiac cycle sequence is shown. Valvular regurgitation is seen as area of decreased signal intensity within left atrium that appears to originate at valve plane and coincide with ventricular systole (*arrows*).

(Fig. 7). The areas (mean ± SD) of mitral jets calculated from cine MR imaging were 8.8 ± 2.0%, 15.9 ± 6.1%, 32.8 ± 21.9%, and 44.2 ± 5.9% in patients with grades I, II, III, and IV regurgitation as determined by left ventriculography. Those by color Doppler flow mapping were 9.6 ± 5.2%, 19.0 ± 9.8%, 31.6 ± 8.7%, and 39.7 ± 2.8%, respectively.

Discussion

Mitral regurgitation is a common clinical problem in patients with combined valvular disease, ischemic heart disease, and cardiomyopathy. Left ventriculography has been considered to be the most accurate means for evaluation of mitral regurgitation [10]. This technique, however, requires catheterization and the use of contrast media. Color Doppler flow imaging is now widely used because it is noninvasive and is accurate for the detection of valvular regurgitation [11, 12]. However, this technique is operator dependent and occasionally limited by body habitus. Cine MR imaging has the advantage that the regurgitant jet is visible as a discrete area of low signal intensity and the procedure is not operator dependent [9, 10]. Our studies also show that in all patients the sites and severities of regurgitant jet were similar on cine MR and color Doppler flow imaging. Although our study shows that the low signal intensity caused by the regurgitant jet during systole is specific for mitral regurgitation, normal systolic outflow from the left ventricle into the aorta also tends to have an apparent jet of decreased signal [8]. In addition, flow rates beyond a certain threshold velocity may not be distinguished with cine MR imaging [8].

In our study, the extent and severity of mitral regurgitation determined by cine MR imaging correlated with those measured by color Doppler flow imaging. Therefore, cine MR imaging can be expected to be as accurate as color Doppler flow imaging. Furthermore, cine MR imaging may have potential in the evaluation of the site and severity of mitral regurgitation in any direction, especially in mitral valve prolapse, compared with color Doppler flow imaging. However, the precise anatomic conditions of mitral valve prolapse could not be defined by cine MR imaging, not because of real-time but

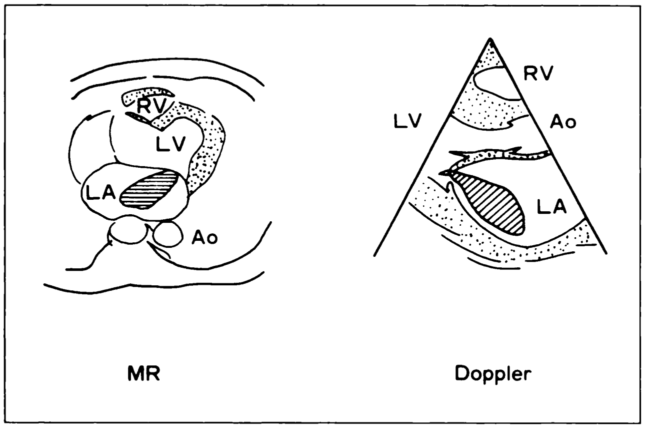
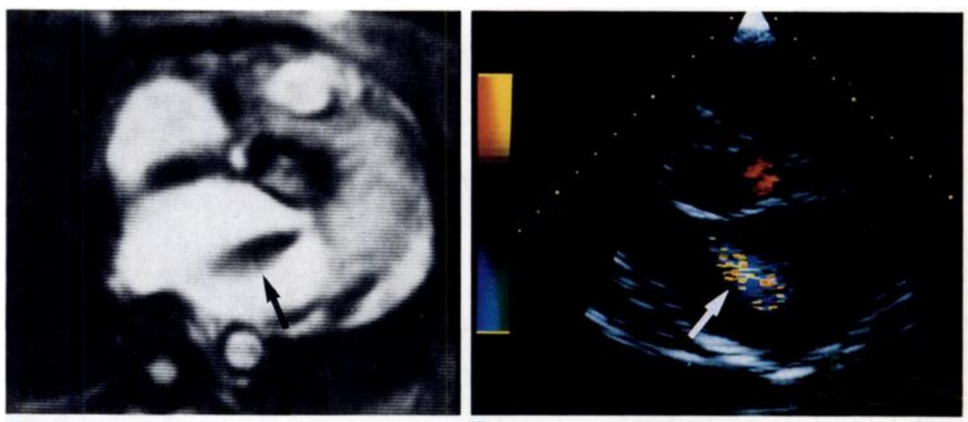


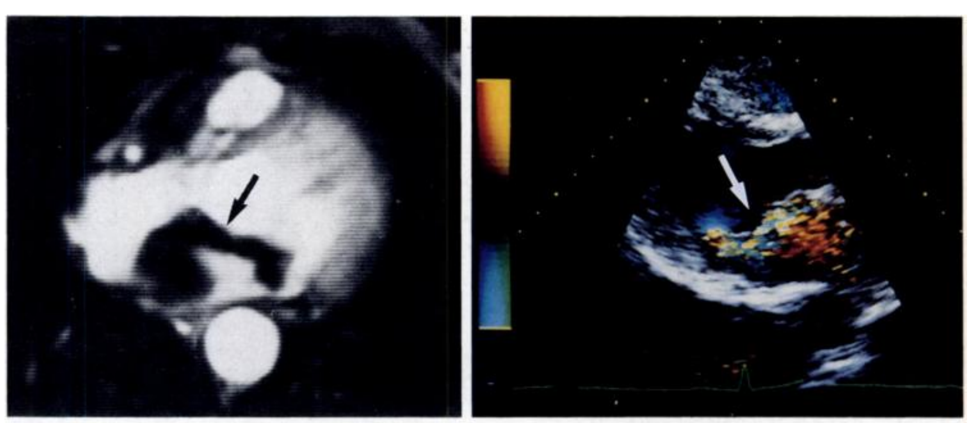
Fig. 2.—Diagram shows mitral regurgitation as detected by cine MR and color Doppler flow imaging. Maximal length and area of regurgitation jet were assessed quantitatively. LV = left ventricle; LA = left atrium; RV = right ventricle; Ao = aorta.



A B

Fig. 3.—48-year-old woman with combined valvular heart disease.

***A* and *B*, Cine MR image (*A*) and Doppler flow image (*B*) show that mitral regurgitant jet spurts from central area of mitral valve into left atrial cavity (*arrows*). Both imaging procedures show similar extent and severity of mitral jet, which was confirmed as grade II (I–IV scale) on left ventriculography.**



A B

Fig. 4.—57-year-old man with mitral valve prolapse of posteromedial scallops.

***A* and *B*, Cine MR image (*A*) and Doppler flow image (*B*) show that mitral jet spurts from posteromedial area of valve and toward anterior wall of left atrium (*arrows*). Extent and severity of mitral jet are similar, which was confirmed as grade IV (I–IV scale) on left ventriculography.**

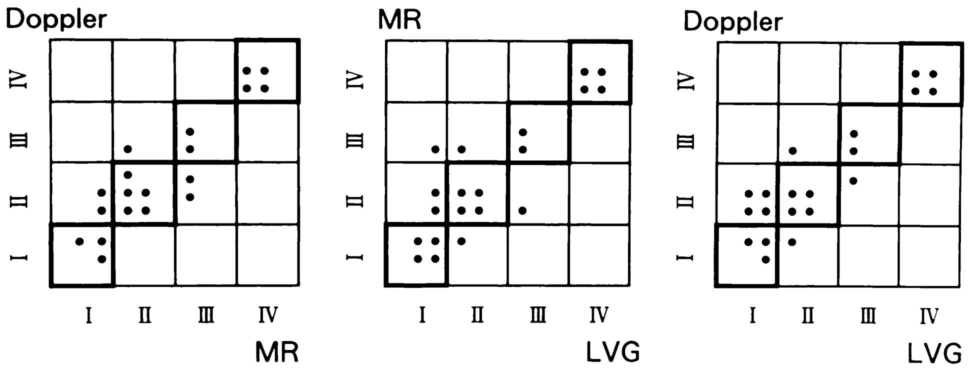


Fig. 5.—Severity of mitral regurgitation determined by cine MR imaging compared with that determined by left ventriculography (LVG) and color Doppler flow imaging. I–IV = degree of mitral regurgitation.

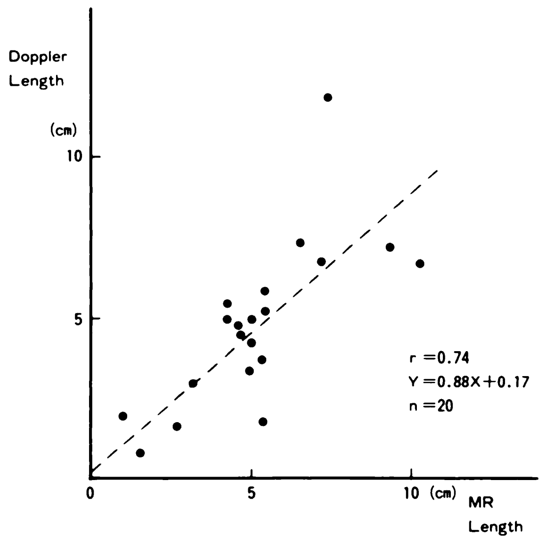


Fig. 6.—Graph shows relationship of maximal length of regurgitant jet as determined by cine MR (x) and color Doppler flow imaging (y). r = correlation coefficient; n = number of cases.

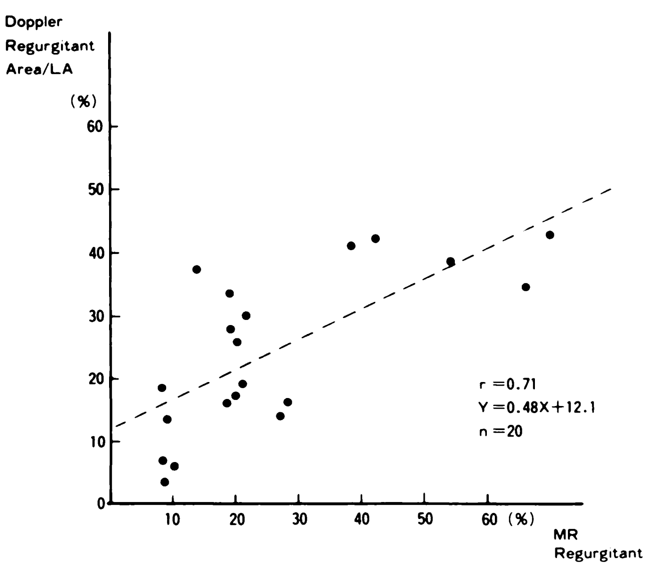


Fig. 7.—Graph shows relationship of maximal area of regurgitant jet as determined by cine MR (x) and color Doppler flow imaging (y). LA = left atrium; r = correlation coefficient; n = number of cases.

because of ECG-gated cardiac imaging. Our cine MR images were obtained in the transaxial plane, whereas color Doppler flow images were obtained in the long-axis plane. The assessment of the integrity and morphology of the valve leaflets is more difficult in transverse section. Although the correlation coefficients of length and area of mitral jet by these two methods were .74 and .71, mitral regurgitation may be assessed more accurately by oblique cine MR imaging [13]. At present, positioning of the patient within the magnet bore is limited, and oblique cine MR imaging is not routinely available with our machine. Oblique cine MR imaging, however, should be investigated further.

In conclusion, cine MR imaging is a promising tool for the noninvasive analysis of mitral regurgitation. The areas of low signal intensity on cine MR imaging were closely correlated with those regions mapped by color Doppler imaging.

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