Cardiac Magnetic Resonance Imaging in Evaluation of Anatomical Structure and Function of the Ventricles

JUN-ICHI SUZUKI, M.D., MASAIRO USUI, M.D., KATSU TAKENAKA, M.D.
KEIKO AMANO, M.D., HISAKO TAKAHASHI, M.D., ICHIRO HASEGAWA, M.D.
TAKAHIRO SHIOTA, M.D., WATARU AMANO, M.D., TSUTOMU IGARASHI, M.D.
TSUGUYA SAKAMOTO, M.D., TSUNEAKI SUGIMOTO, M.D.
AND JUN-ICHI NISHIKAWA, M.D.*

Cardiac magnetic resonance imaging (MRI) is being widely employed for evaluation of cardiovascular anatomies and functions. However, the indications for cardiac MRI to obtain information which cannot be obtained using other conventional methods have not yet been determined.

To demonstrate usefulness of MRI in delineating the apex of the left ventricle and free wall of the right ventricle, end-diastolic short axis MRI images were obtained in 20 patients with apical hypertrophy and in 9 normal volunteers. To compare the accuracy of estimations of left ventricular volumes obtained using the modified Simpson's method of MRI with that using the MRI area length method, 19 patients, in whom left ventriculography had been performed, were studied.

The apex of the left ventricle was evaluated circumferentially and distribution of hypertrophied muscles was defined. Sixty-five percent of the length of the right ventricular free wall was clearly delineated. Correlation coefficients of the ejection fraction between MRI and angiography were 0.85 with the modified Simpson's method of MRI, and 0.62 with the area length method of MRI.

Three themes were chosen to demonstrate good clinical indications for cardiac MRI.

CARDIAC magnetic resonance imaging (MRI) is being accepted rapidly in clinical cardiology as a noninvasive method for visualization of cardiac anatomical structures and for evaluation of function of the cardiovascular system. This acceptance has come about since the techniques of electrocardiogram gating¹ and gradient angle rotation² were introduced. However, due to the high price of the huge MRI instruments and the high maintenance expenses it should not be tolerable to use MRI to obtain only information that can be easily acquired by other conventional methods, such as echocardiography. In this respect, in the present study, three different kinds of indications for MRI were chosen for demonstration. They were: 1) Determination at the apical level of hypertrophy patterns in apical hypertrophy (AH)³; 2) Evaluation of the thickness of the right ventricular free wall⁴,⁵; 3) Reconstruction of left ventricular volumes using short axis images according to the modified Simpson's rule⁶.

Key words:
Magnetic resonance imaging
Apical hypertrophy
Right ventricular free wall
Left ventricular ejection fraction

METHODS

Subjects
The pattern of hypertrophy at the apical level

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The Second Department of Internal Medicine and *Department of Radiology Faculty of Medicine, University of Tokyo, Tokyo, Japan

Mailing address: Jun-ichi Suzuki, M.D., The Second Department of Internal Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyoku, Tokyo 113, Japan

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was studied in 20 patients with AH. Hypertrophy at the apical level was defined as hypertrophy of the wall’s thickness equal to or more than 15 mm, associated with deep negative T waves on electrocardiogram. Patients with a wall thickness equal to or more than 17 mm at the basal level were excluded. The wall thickness of the right ventricular free wall was measured in 9 healthy volunteers. Electrocardiographic and echocardiographic findings were all normal in 9. The applicability of Simpson’s method to calculation of the ejection fraction using MRI was studied in

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19 patients in which roentgenologic angiography had been performed and who had no wall motion abnormality.

**MRI imaging:**

An electrocardiogram-gated saturation recovery spin echo was utilized for imaging pulse sequence. Echo time was 34 msec and images were obtained 74 msec and 374 msec after the R wave trigger for end-diastolic and end-systolic images, respectively. The reconstruction matrix was $256 \times 256$ with spatial resolution of 0.16–0.20 cm and slice thickness was 1.0 cm. Long axis and short axis images were obtained in the paraxial planes, with patients in right anterior oblique positions.

**Measurement of the left ventricular wall thickness at the apical level in AH:**

The distribution of hypertrophy with wall thickness equal to more than 15 mm at the apical level was determined on MRI end-diastolic short axis images. The distance between the planes for images and the tips of the apex of the left ventricle was $25 \pm 5$ mm.

**Measurement of the right ventricular free wall thickness:**

Sixteen short axis images were used. The wall thickness of the right ventricle was measured at centimetre intervals in the zone of the right ventricular free wall with clear epicardial and endocardial margins.

**Modified Simpson’s method using short axis MRI images:**

The lengths of the end-diastolic and systolic long axes of the left ventricle were measured on long axis images, and the end-diastolic and systolic areas of the intraventricular cavity of the left ventricle were measured on short axis images at four levels (Fig. 1). The modified Simpson’s method was used for calculation of end-diastolic and systolic left ventricular volumes. Left ventricular volumes were also calculated by area-length methods using MRI long axis images. The values thus obtained were compared with those obtained using the single plane area-length method of angiography.

**Statistical analysis:**

All measurements were expressed as the mean ± 1SD (standard deviation). Differences between the two groups were tested by Student’s paired t-test, and statistical correlations were made with linear regression analysis.

**RESULTS**

**Distribution of hypertrophy at the apical level in AH:**

Hypertrophy at the apical level was found to be located at the septal-anterior-lateral-posterior wall in 2 patients (Fig. 2), septal-anterior-lateral wall in 7 patients, septal-anterior wall in 2 patients, the septum in 1 patient, anterior-lateral wall in 2 patients (Fig. 2), anterior wall in 3 patients and the lateral wall in 3 patients. In 6 of 20 patients with AH, hypertrophied muscles at the apical level could not be detected on MRI long axis images corresponding to left ventriculography in the right anterior oblique position.
**Delineation of the right ventricular free walls:**

The total length of the right ventricular free wall measured in 16 short axis images from 9 healthy subjects was 256.1 cm, and the total zone with clear margins was 163.8 cm. The ratio of the latter to the former length was 0.65. Thus, 65% of the right ventricular free wall was measurable on magnetic resonance short axis images. The mean thickness of the right ventricular free wall measured at 159 points was 0.20 ± 0.08 cm (Fig. 3).

**Evaluation of left ventricular volumes and ejection fraction:**

Left ventricular end-diastolic volumes measured using the modified Simpson’s method of MRI, the area length method of MRI and angiography were 141 ± 33 cm³, 113 ± 32 cm³ and 144 ± 33 cm³, respectively. The end-diastolic volume measured using the area length method of MRI was significantly smaller than that measured by angiography (p < 0.01). Left ventricular endsystolic volumes determined by the modified Simpson’s method of MRI, the area length method of MRI and angiography were 57 ± 27 cm³, 45 ± 27 cm³ and 53 ± 28 cm³, respectively. Ejection fractions obtained by these 3 methods were 0.61 ± 0.12, 0.62 ± 0.12 and 0.64 ± 0.12, respectively. The correlation coefficient and regression line between the value for the ejection fraction obtained using the modified Simpson’s method of MRI and that obtained by angiography were \( r = 0.85 \) and \( y = 0.89X + 0.10 \), respectively (p < 0.01). The correlation coefficient and regression line between the value for the ejection fraction obtained using the area length method of MRI and angiography were \( r = 0.62 \) and \( y = 0.49 + 0.34 \), respectively (p < 0.01).

**DISCUSSION**

A spade-like configuration on the left ventriculogram in the right anterior oblique projection⁰ has been used as a diagnostic criterion for AH. But in this projection, anatomical information can be obtained only for apical anterior and apical posterior (inferior) walls. Specific types of AH which have localized hypertrophied muscles at the apical septum or apical lateral wall can not be diagnosed using this projection. In cases with deep negative T waves of unknown etiology, circumferential evaluations of the apex should be performed. For this purpose, MRI short axis images are very useful⁰.

Sixty-five percent of the length of the right ventricular free wall of normal volunteers was delineated clearly using spin-echo MRI. The remaining 35% could not be distinguished from surrounding tissues because of artefacts caused by chemical shifts, changes in RR intervals during scanning and phases disturbed by movements. A
rough spatial resolution of 1.6–2.0 mm was not always enough to discriminate the myocardium from the trabeculae and the subepicardial fat. However, MRI is still thought to be the first-choice method for evaluation of the right ventricle because it is not easy to cover a wide area of the right ventricle by conventional methods.

The 74 msec and 374 msec post-trigger time points were chosen as timings for the acquisition of MRI signals for end-diastole and end-systole, respectively. As 74 msec is usually shorter than the pre-ejection period, this timing is usually earlier than the beginning of the mechanical contraction of the left ventricle, thus enabling correct end-diastolic images to be obtained. In contrast the 374 msec post-trigger time point does not always exactly coincide with end-systole, but there was no significant overestimation in measurements of end-systolic volume by the modified Simpson's method of MRI. Thus, this end-systolic timing showed be permissible. In the present study, the ejection fraction was obtained more reliably by the modified Simpson's method of MRI than by the area length method of MRI, since the latter underestimated left ventricular volumes, probably due to slight deviation of the scanning plane from the true long axis plane of the left ventricle.

Using MRI, we are thus able to analyze a wide area of the cardiac anatomy something which conventional methods cannot achieve. MRI enables us to evaluate the apex of the left ventricle circumferentially and 65% of the length of the right ventricular free wall. In addition, MRI can be considered a reference standard for measurements of ventricular volumes since Simpson's algorithm can be exactly applied to this method.

REFERENCES