

HEART WALL MOTION ANALYSIS AND DISPLAY USING MRI TAGGING

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Abstract: In this paper, we developed a left ventricular (LV) wall motion analysis method, and developed a display method of the motion on personal computer monitor.

To know precise rotation or deformity, identifiable landmarks must be located. The MRI tagging makes it possible to estimate the regional wall motion noninvasively. We tried to estimate the precise LV wall motion by the MRI tagging.

Tagging is achieved by selective saturation pulse method. The difference of the signal intensity between tagged and nontagged regions persist for 400-700 milliseconds.

We display the tag point movement as animation, and display the rotation & contraction curve on the same computer monitor.

Keywords: magnetic resonance imaging, tagging, wall motion display

1 INTRODUCTION

A quantitative estimation of regional wall motion is required to evaluate the severity of heart disease or the cardiac function. Echogram, EKG-gated scintigraphic angiocardiology and coronary angiography are used to estimate the regional wall motion. But to know precise rotation or deformity, identifiable landmarks must be located. The landmarks have been supplied by the implanted radiopaque beads or by the bifurcations of the coronary arteries [1,2]. The MRI tagging makes it possible to estimate the regional wall motion noninvasively. We tried to estimate the precise LV wall motion by the MRI tagging. We can determine the tag points in a normal volunteer for 700 milliseconds.

2 METHODS

2.1 MRI acquisition

A normal volunteer (men, aged 49) was imaged on a 1.5T scanner (Toshiba MRT-200). Tagging is achieved by selective saturation pulse method [3,4]. Experiments were performed using a field echo method, with time to echo (TE) equaling 15 milliseconds, repetition time (TR) equaling 50 milliseconds flip angle (FA) equaling 30 degrees and averaging four excitations. The difference in the signal intensity between tagged and nontagged regions persist for 700 milliseconds.

After positioning the volunteer in the MR imager, a series of scouting images was acquired so that true short axis images were obtained. The tag lines were placed perpendicularly to the image planes at end diastole. The four chamber view image with four parallel tags was also obtained. Figure 1 shows the images.

2.2 Data analysis

2.2.1 Image processing

The obtained static images of MRI tagging were transferred through video-floppy to an IBM-compatible personal computer, where video processor board converted each image to (256x256 matrices, gray levels) digital data.

First, LV endocardial and epicardial borders were manually marked at 5-10 millimeters suitably. And these points were linked using B-spline curve (Figure 1). The contours of LV endocardium and epicardium made it easier to settle the intersections with tag lines.

The tag lines make twelve intersections on endocardium and epicardium respectively on short axis images and eight on long axis images. The tag lines have width (4 mm), so the intersections were settled on the centerlines.

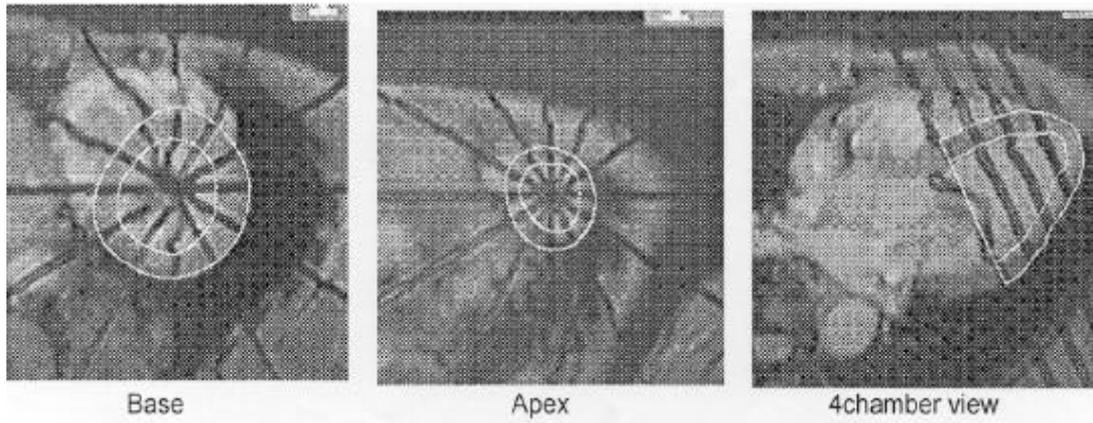


Figure 1. Contours of LV endocardium and epicardium

2.2.2 Animation display

On personal computer monitor, we display MR image, wall contour, tag point and graph data every 100 milliseconds (Figure 2).

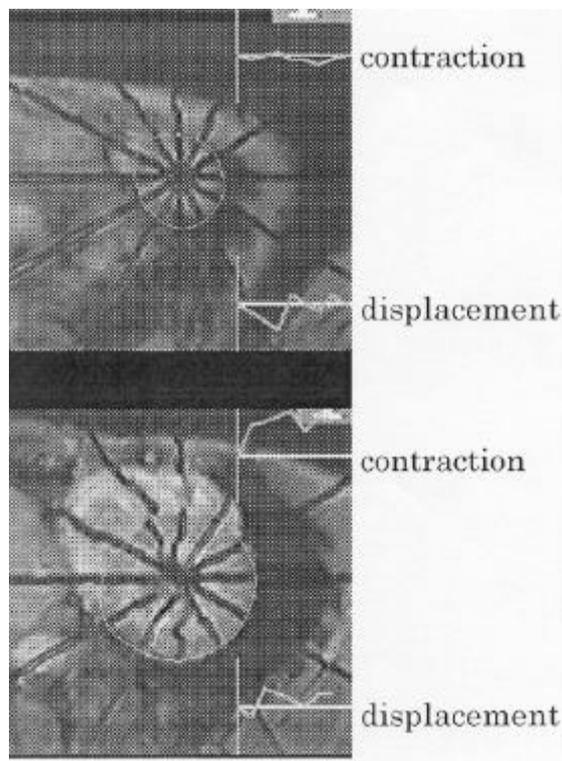


Figure 2. Animation display

3 RESULT

The tag lines make twelve intersections on endocardium and epicardium respectively on short axis images and eight on long axis images. The tag lines have width (4 mm), so the intersections were settled on the centerlines.

These tag points are obtained every 100 milliseconds, Figure 3 shows the apical slice of the volunteer. There was systolic counterclockwise and diastolic clockwise rotation. Displacement of anterior-lateral wall was larger than ventricular septum. Tag points 6-9 represent anterior-lateral wall of endocardium. By magnification these tag points seemed to form hysteresis loops.

Figure 4 shows the 4 chamber view slice of volunteer 1. During systole LV endocardium and epicardium were contracted and also moved toward apex. On endocardium the basal tag points seemed to form hysteresis loops. On the epicardium tag points seemed simply moved toward apex, because wall thickening and contraction canceled each other.

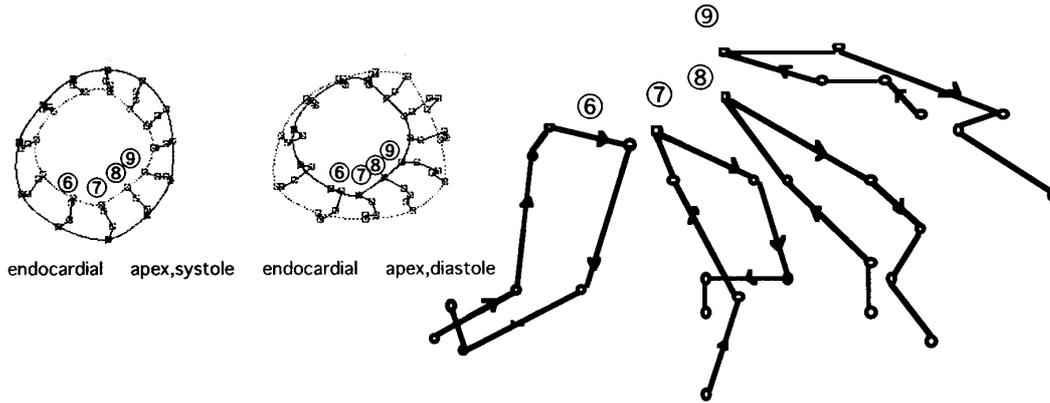


Figure 3. Tag point movement of volunteer 1 on short axis

Animation display enable us, to understand heart wall motion clearly. To display base and apex, the difference of the wall motion becomes obvious. And comparison of short axis and long axis, or comparison of another person, or comparison of another period of same person are possible.

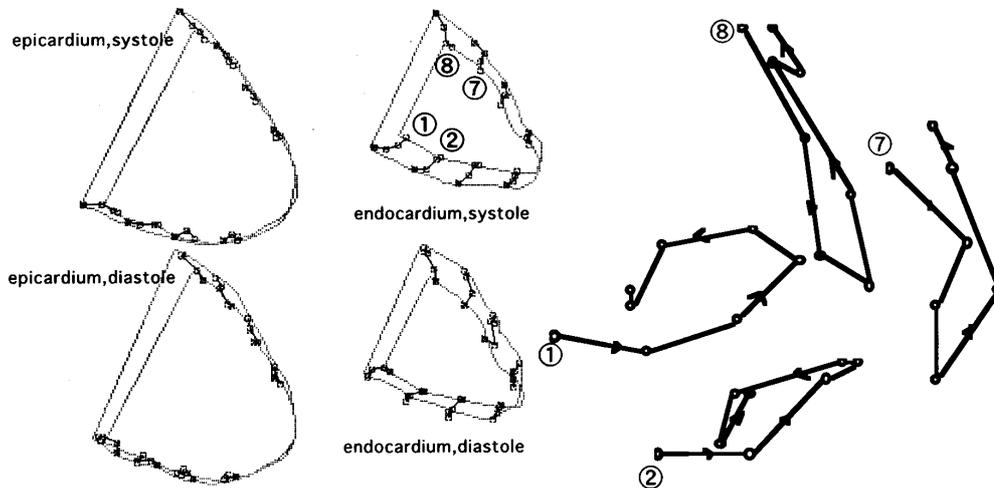


Figure 4. 4 chamber view slice of volunteer 1

4 DISCUSSION

In 1970s, to analyze heart wall motion, radiopaque beads were implanted in the midway [1]. Coronary cineangiogram was one of the method to analyze heart wall motion [2,3,4]. From the end of 1980s MRI tagging method was used for heart wall motion analysis [5-9]. MRI tagging is almost noninvasive and is especially useful for analysis of the motion of epicardium and endocardium. Up to the present many reports were mentioned about left ventricular deformation, wall thickness and wall motion. But all of them were about left ventricular systolic analysis [10-17]. In diastole, tags became obscure, and it became difficult to determine the intersections of tag lines and endo- or epicardium. We tried to determine the intersections in diastole by tracing the wall contour first.

So it disappeared to be possible that the intersections were determined during 400-600 milliseconds after enddiastole.

In the beginning, we interpreted the hysteresis loop of tag points on short axis section as phase gap between rotation and contraction. But the hysteresis loop seems to be formed by the whole heart shift mainly. On long axis section we also interpreted the hysteresis loop as phase gap between contraction and displacement toward apex. But the hysteresis loop also seems to be formed by the whole heart shift.

Buchalter et al mentioned that in systole the mean of the torsion angles of the apical slice, relative to the mean of the torsion angles of the basal slice was 19.1 ± 2.0 degrees. Our result of the torsion angles were 21.7 degrees in the volunteer.

The four parallel tagging planes were implemented on long axis sections and six radial tagging planes on short axis sections. Minimum time per tagging plane was about 15 milliseconds from the

center of the tagging radiofrequency (RF) pulse to the center of the next tagging pulse, so we get first image 50-100 milliseconds after true end-diastole. These delay time after end-diastole seems to make it easy that we assess the heart wall motion in diastole. Therefore to adopt 200-300 milliseconds as the delay time after R wave, it seems to be easier to assess the diastolic heart wall motion.

In order to analyze left ventricular wall motion, there are many component, that is (apex, base), (septum, lateral wall), (endocardium, epicardium), (contraction, rotation, displacement). The animation display seems to enable us to understand the wall motion more clearly.

5 CONCIUSION

Animation display enable usto understand heart wall motion clearly, especially when there is phasal gap, and the difference must be emphasized on the personal computer monitor.

The contours of endocardium and epicardium mae it easy to settle the intersections with tag lines. MRI tagging seems to be useful to assess LV wall motion not only in systole but also in diastole.

REFERENCES

- [1] Neil S. Ingels, Jr., Ph.D., Evaluation of Methods for Quantitating Left Ventricular Segmental Wall Motion in Man Using Myocardial Markers as a Standard, *Circulation* **61** (1980) 966-972.
- [2] Florence H. Sheehan, M.D., Advantages and Applications of the Centerline Method for Characterizing Regional Ventricular Function, *Circulation* **74** (2) (1986) 293-305.
- [3] Maurice B. Buchalter, Noninvasive Quantification of Left Ventricular Rotational Deformation in Normal Humans Using Magnetic Resonance Imaging Myocardial Tagging, *Circulation* **81** (1990) 1236-1244.
- [4] Sheng-Jing Dong, M.D., Left Ventricular Wall Thickness and Regional Systolic Function in Patients With Hypertrophic Cardiomyopathy, *Circulation* **90** (1994) 1200-1209.
- [5] Udo Sechtem, Cine MR Imaging-. Potential forthe Evaluation of Cardiovascular Function. *AJR* **148** (1987) 239-246.
- [6] Tsunehiko Nishimura, Cine MR Imaging in Mitral Regurgitation-. Comparison with Color Doppler Flow Imaging, *AJR* **153** (1989) 721-724,
- [7] Matthias G. Dulce, Quantification of the Left Ventricular Volumes and Function with Cine MR Imaging: Comparison of Geometric Models with Three-dimensional Data, *Radiology* **188** (1993) 371-376.
- [8] Alistair A. Young, Ph.D., Validation of Tagging with MR Imaging to Estimate Material Deformation, *Radiology* **138** (1993) 1 88: 1 0 1.
- [9] Elias A. Zerhouni, M.D., Human Heart: Tagging with MR Imaging- A Method for Noninvasive Assessment of Myocardial Motion, *Radiology* **169** (1988) 59-63.
- [10] Leon Axel, Ph.D., M.D., MR Imaging of Motion with Spatial Modulation of Magnetization, *Radiology* **171** (1989) 841-845.
- [11] Leon Axel, Ph.D., M.D., Heart Wall Motion: Improves Method of Spatial Modulation of Magnetization for MR Imaging, *Radiology* **172** (1989) 349-350.
- [12] Bradley D. Bolster, Jr. , B EE, Myocardial Tagging in Polar Coordinates with Use of Striped Tags, *Radiology* **177** (1990) 769-772.
- [13] Peter W. Pflugfelder, Comparison of Cine MR Imaging with Doppler Echocardiography for the Evaluation of Aortic Regurgitation, *AJR* **152** (1989) 729-735.
- [14] Kentaro Matsumura, Determination of Cardiac Ejection Fraction and Left Ventricular Volume: Contrast-Enhanced Ultrafast Cine MR Imaging vs IV Digital Subtraction Ventriculography, *AJR* **160** (1993) 979-985.
- [15] Andre C. Eichenberger, Aortic Valve Pressure Gradients in Patients with Aortic Valve Stenosis-. Quantification with Velocity-Encoded Cine MR Imaging, *AJR* **160** (1993) 971-977.
- [16] Alistair A. Young, Ph.D., Two-dimensional Left Ventricular Deformation During Systole Using Magnetic Resonance Imaging With Spatial Modulation of Magnetization, *Circulation* **89** (1994) 740-751.
- [17] Macgowan GA, Noninvasive Measurement of Shortening in the Fiber and Cross-Fiber Directions in the Normal Human Left Ventricle and in Idiopathic Dilated Cardiomyopathy, *Circulation* **96** (1997) 535-541.

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