左心室画像の処理と心機能の表示

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LEFT VENTRICULAR IMAGE PROCESSING AND DISPLAYS OF CARDIAC FUNCTION

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1. INTRODUCTION

Left ventricular images, obtained by x-ray, ultrasound, radionuclides and others, have been used to diagnose cardiac diseases. However, there are few methods to analyze the images and display quantitative cardiac functions graphically using digital computers. In this paper, there are shown some image processing and data displaying techniques to apply to the left ventricular images obtained by x-ray and ultrasound developed by the authors' group.

2. IMAGE PROCESSING OF 2-D ANGIO- AND ECHOCARDIOGRAMS

For the analysis of left ventricular functions, we need to detect the left ventricular (LV) boundaries on consecutive cine- or video-frames over a cardiac cycle. Manual techniques have been used to trace the LV boundaries, but they are very troublesome and time-consuming, especially when a large number of images is to be treated.

Some groups have been working for detecting LV boundaries automatically. Our method to detect LV boundary from an angiocardiogram is based on the gradient image of grey levels of the angiocardiogram [1]. Figure 1 shows an example of consecutive boundaries detected. 2-D echocardiograms, digitized directly or through a video tape recorder, can be processed by various methods. One of our method [2] is as follows: An operator picks up about 10 points which can be guessed to exist on the LV boundary of the echo image at an end-diastolic phase. 2-D echo data are rearranged into radially scanned data from the center of gravity of the closed curve made by connecting these initial points. Scanning the radially rearranged data and applying a thresholding technique, we can automatically obtain the boundary point of the left ventricle on each radial line. Figure 2 shows LV boundary curves during a cardiac cycle.

We can get various quantitative cardiac functions from the consecutive LV boundaries obtained above, such as volume change, cardiac output, regional wall motion and so on [3]. Figure 3 is a 3-dimensional display of the wall motion at every point around the LV cavity. By comparing two LV boundaries at the end-diastolic (ED) and end-systolic (ES) phases, we can observe the wall movement between ED and ES phases as shown in Fig. 4; the left side is for rested condition (control) and the right side is after anginal attack induced by rapid pacing of the right atrium (pacing). Figure 5 gives the percentage shortening of regional wall segment and we can observe the regional contractility on this figure.

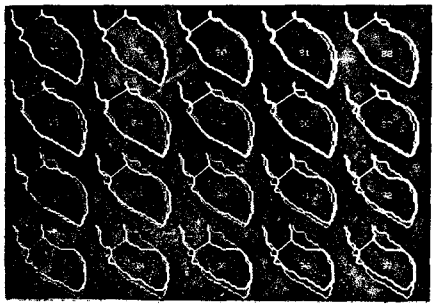

Fig. 1 Consecutive LV boundaries from angiocardiograms

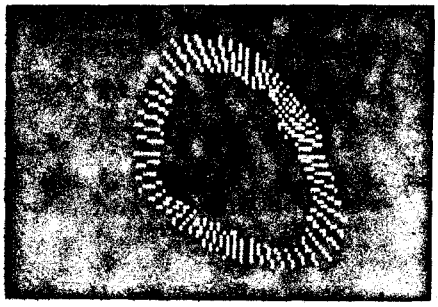

Fig. 2 Consecutive LV boundaries during a cardiac cycle from echo

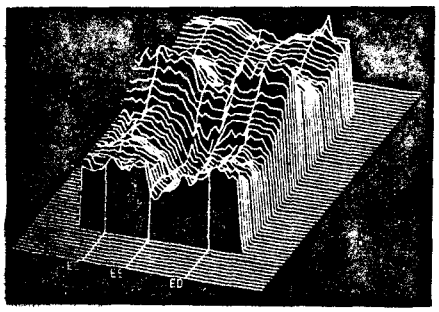

Fig. 3 3-D display of LV wall motion

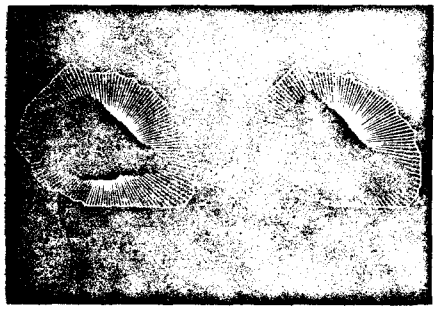

Fig. 4 LV wall movements between ED and ES phases

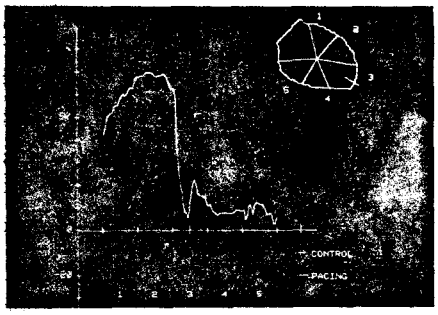

Fig. 5 Percentage shortening of left ventricle

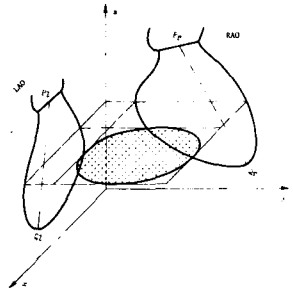

Fig. 6 3-D reconstruction of left ventricle from biplane angiocardiograms

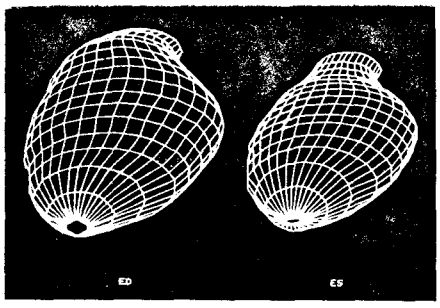

Fig. 7 Wire-framed 3-D images of left ventricle

Fig. 8 Shaded 3-D left ventricle

3. 3-D RECONSTRUCTION OF LEFT VENTRICLE FROM BIPLANE ANGIOCARDIOGRAMS AND 2-D ECHOCARDIOGRAMS

X-ray angiocardiography and ultrasound echocardiography are usually used for examination of cardiac functions. In the case of angiocardiography, the monoplane method from the right anterior oblique position and the biplane method from the right and left anterior oblique positions are often used. On the other hand, in the case of 2-D echocardiography, short axis and apical long axis views and other views are used to get various cross sectional images of the heart. If we obtain 3-D images of left ventricle, they may reveal more exact information about cardiac functions to medical doctors.

Figure 6 shows a schematic diagram of the 3-D reconstruction method using biplane angiocardiograms of RAO 30° and LAO 60° projections at the same cardiac phase [4]. When we slice the left ventricle by a horizontal plane to the body axis, we get two line segments cut by the two boundary curves on RAO and LAO planes. The cross section of the left ventricular cavity on this horizontal plane is assumed to be an ellipse which is inscribed in the rectangle made by the two line segments of RAO and LAO projections. The 3-D left ventricle may be reconstructed by stacking these ellipses from the apex to the aortic valve. Figures 7 and 8 give 3-D wire-framed and shaded left ventricles. By comparing two 3-D images at ED and ES phases, we can calculate a percentage shortening for the 3-D left ventricle which is shown in Fig. 9 by pseudo colors.

Fig. 9 3-D percentage shortening of left ventricle (pseudo color)

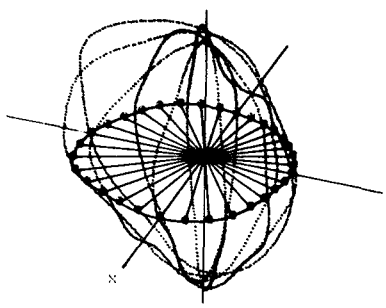

Fig. 10 6 LV boundaries and a cross section with 32 sample points

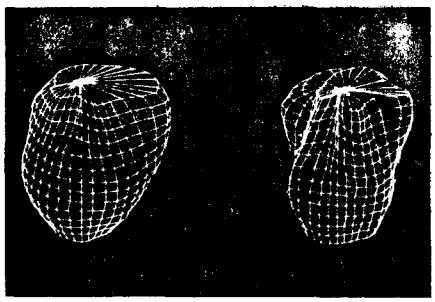

Fig. 11 Wire-framed 3-D images of left ventricle from 2-D echocardiograms

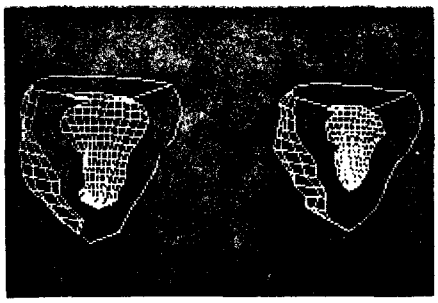

Fig. 12 Logitudinal cross sections of 3-D myocardium

There are two ways to reconstruct 3-D images of the left ventricle using 2-D echocardiograms: One is the way to use short axis images changing the position of ultrasound probe on the chest wall [5] and the other is the way to get several cross sectional images of apical long axis view rotating the probe around an axis keeping the tip of the probe at the same position near the apex on the chest wall [6]. Figure 10 shows the 6 boundary curves and a cross section with 32 sample points perpendicular to the rotating axis and Fig. 11 gives a pair of wire-framed 3-D images of the left ventricle reconstructed by using 16 cross sections. The left side of this figure is at ED phase and the right is at ES phase.

By using two sequences of consecutive endocardial and epicardial 3-D left ventricular shapes, we can obtain 3-D images of LV myocardium. Figure 12 shows longitudinal cross sections of left ventricular myocardium at ED and ES phases. From the 3-D reconstructed myocardial images during a cardiac cycle, we can obtain time variations of the wall thickness of the 3-D left ventricle and 3-D percentage wall thickening of the myocardium, and also we can observe these results displayed in pseudo colors on a TV monitor.

4. CONCLUDING REMARKS

We discussed image processing techniques of 2-D left ventricular images obtained from angiocardiographic and echocardiographic examinations and showed 3-D reconstruction methods of left ventricular cavity and myocardium from 2-D images in this paper. Quantitative analyses of 2-D and 3-D left ventricular images and displays of cardiac functions were also shown, and these results may be useful for clinical diagnosis. On the other hand, we developed a prototype of microcomputerized on-line image processing system for 2-D echocardiography [2]. By using this system, left ventricular boundaries and some quantitative cardiac functions can be obtained in a short time.

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