ULTRASONIC THREE-DIMENSIONAL IMAGING AND VOLUME: AN IN VITRO EVALUATION

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We have developed a system for building three-dimensional (3D) reconstructions of various organs in the body, including the left ventricle (LV). In this technique a series of real time ultrasound scans are acquired in an arbitrary manner from all parts of the organ, outlined with a light-pen, and combined into a set of 3D points on the organ surface using information from a 3D acoustic position locating system. A computer model is then fit to these data; volume is found from the model. Since the model makes no assumptions about geometry it should give accurate volumes even for irregular objects such as the diseased LV. The overall worst case error of the system for locating 3D surface points was found to be 0.6 cm; this error was largely explained by the ultrasound resolution of 0.23 cm (lateral resolution), and the 3D locator resolution of 0.27 cm (in the worst case). The ability of the system to find volume in vitro was tested on balloons, kidneys and LV molds. Thirty volume trials on 10 balloons gave 27 out of 30 calculations within 1.85% of true volume, with an R of .999. Eighteen trials on 6 kidneys gave 17 out of 18 calculations within 5.1% of true volume, with an R of .997. Fifteen trials on 5 human LV molds gave 13 out of 15 calculations within -5.9% of true volume, with an R of .986. We conclude that the measured 3D point resolution represents only a worst case source of difficulties, and that it is possible to obtain very accurate volumes with this technique, at least in the in vitro situation.

OBJECTIVE ECHOCARDIOGRAPHIC QUANTITATION OF LEFT VENTRICULAR VOLUMES BY USE OF AUTOMATED COMPUTERIZED EDGE-DETECTION ANALYSIS IN CANINES AND HUMANS

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Because of the subjective nature of determining left ventricular (LV) volume (V) from manually drawn (MD) two-dimensional echocardiograms (2DE), a new automated computerized edge detection algorithm (ACED) was developed and compared to MD and cineangiography. LVV's were calculated in 13 canines and 10 humans with 2DE quality required for quantitative ACED analysis. Images were digitized in a 64 x 64 matrix in real-time and processed using space-time smoothing and dynamic range expansion. ACED employed a 2D Laplacian operator thresholded to an echo amplitude. ACED-derived LV short axis cross-sectional areas (A) (4/dog, 2/human) were compared to MD-A. End-diastolic (ED) and end-systolic (ES) volumes were then determined using a modified Simpson reconstruction. Correlation ACED vs MD (N=number, R=coefficient):

	Canines			Humans		
	N	R	SEE	N	R	SEE
EDA	52	.90	1.4 cm^2	20	.95	5.4 cm^2
ESA	52	.89	1.5 cm^2	20	.93	2.65 cm^2
EDV	13	.92	10.8 cc	10	.97	21.9 cc
ESV	13	.91	7.5 cc	10	.98	8.0 cc
Correlation 2DE-ACED vs cineangiography:						
EDV	13	.93	11.4 cc	10	.88	50.0 cc
ESV	13	.96	5.1 cc	10	.77	37.9 cc

CONCLUSIONS: Left ventricular cross-sectional areas and volume may be accurately obtained by use of automated computerized edge detection analysis. Importantly, this new method is objective and may offer the advantage of speed.

THREE-DIMENSIONAL QUANTITATIVE ANALYSIS OF MULTIPLE TWO-DIMENSIONAL ECHOCARDIOGRAPHIC VIEWS

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In order to derive quantitative information about left ventricular wall motion and volume, we developed a system for integration of multiple nonparallel two-dimensional echocardiographic images into a three-dimensional (3D) reconstruction framework. One long axis and three short axis views of the left ventricle were recorded from the left parasternal border using a wide angle phased array sector scanner. Three-dimensional Cartesian coordinates for each image plane were obtained with a modified mechanical B scan arm. End-diastolic and end-systolic frames for each plane were selected from a videodisc recording using ECG gating. Endocardial outlines and 3D coordinates for each image were entered into a VAX computer and displayed in 3D perspective on a graphics display terminal using an IPAD software package. Spline fitting was used to connect adjacent points on each of the images to produce a composite 3D image at end-systole and at end-diastole which can be rotated, translated and magnified on the screen. This system permits visualization and integration of multiple 2D echo outlines of the left ventricle in 3D perspective, and should prove useful in quantitative analysis of wall motion and volume.

DIGITAL ENHANCEMENT OF TWO-DIMENSIONAL (2D) ECHOCARDIOGRAMS

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Digital image processing techniques similar to those developed for the enhancement of video- angiocardiograms were applied to clinical echocardiograms produced by a phased array sector scanner. Two main goals were the automatic reduction of speckle noise in normal 2D-echocardiograms and the extraction of regions containing contrast echos from contrast echocardiograms. The video recordings of echocardiograms were digitized using a matrix of 256*256 picture elements per video field. From the digitized sector scan images (DSS), pictures with improved amplitude resolution were computed by ECG- gated averaging of typically 8 to 12 DSS. These preprocessing techniques simplified the computerized detection of ventricular borders and improved the accuracy of the densitometric evaluation of myocardial echos for tissue characterization. Image subtraction techniques were used to extract from DSS selectively those regions which contained echos from contrast material. These could otherwise not be distinguished from bordering tissue. This technique was used as a preprocessing step in semi-automatic volume determination from contrast echocardiograms. A new pseudocolor display was developed for simultaneous, but specific display of contrast and tissue regions. Conclusion: Both the qualitative and the quantitative evaluation of noncontrast and contrast 2D echocardiograms can be improved by digital preprocessing techniques which can be implemented using advanced systems now being developed for digital video angiocardiography.