A NEW TECHNIQUE FOR THE COMPUTER DETERMINATION OF TIME-COURSE OF LEFT VENTRICULAR VOLUME

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ABSTRACT

The time-course of left ventricular volume is valuable as a clinical diagnostic tool. It's usefulness is limited at present by the tedious processing required to extract volume information from cineangiograms. This paper proposes a completely computer-oriented approach to the task of volume calculation. A flexible television/computer interface converts videoangiocardiograms into digital form in real time. A simulation model is used to test various digital filtering techniques. Reduction of noise and artefacts is illustrated. A new technique is presented, using a form of video densitometry which has definite advantages over boundary detection methods.

INTRODUCTION

Angiocardiograms are the most widely used source of information on left ventricular function. The time-course of left ventricular volume (LVV) is valuable for diagnostic purposes, but difficult to obtain. Manual frame-by-frame extraction of volume information from cineangiocardiograms is inefficient and time consuming. (1)

DATA CONVERSION

A television/computer interface has been developed which converts videoangiograms into digital form in real time. (2) It incorporates flexibility in resolution and temporal and spatial sampling. Thus, only the pertinent data is converted.

SIMULATION

A computer simulation of the ellipsoid model (3) of the left ventricle provides a vehicle for generating simulated conversions of live data. A schematic of this model is shown in Figure 1. X-rays are absorbed by different media according to an exponential law incorporating the medium thickness, d, and absorption coefficient, μ. Consider an ellipsoid ventricle of minor diameter, D, and surrounded by tissue. The equation of I, the intensity of x-rays at any point in the viewing plane is:

$$I = I_o e^{-[(D-d)\mu_1 + d\mu_2]} \quad (1)$$

where I_o is the source intensity,
U_1 is the absorption coefficient of tissue,
U_2 is the absorption coefficient of opacified blood
and d is the depth of opacified blood at any point in the ellipsoid. (d varies from O to D)

When d=o, (all points outside the ellipsoid boundary), the equation for the intensity (background) is:

$$I_b = I_o e^{-D\mu_1} \quad (2)$$

Substitution of (2) in (1) yields the general equation.

$$I = I_b e^{-d(\mu_2 - \mu_1)} \quad (3)$$

Therefore, given μ_1 and μ_2, background intensity I_b, and ellipsoid axes lengths, d can be calculated, and thus I, for every point in an assumed spatial matrix of samples.

PROCESSING TESTS

This model was used to test previously developed temporal and spatial digital filtering methods (4,5). Their effectiveness in cases of low dye concentration is shown in a series of computer-generated CRT outputs in figure 2. Three fields (64 x 96 points), 1/30 second apart, simulate the video image during systole. At $\mu_2/\mu_1 = 1.43$ (low contrast), uniform additive noise produces a s/n ratio at maximum d of approximately 1:1. Averaging of successive heart cycles reduces noise and artefacts. The results of an eighth order average are shown. Subsequent non-linear enhancement produces a record in which a simple threshold criterion will detect all boundaries.

NEW TECHNIQUE

An alternate technique is proposed, based on a videodensitometry method incorporating the series of previous equations. Take the natural logarithm of both sides of equation (3) and rearrange.

$$\ln I_b - \ln I = d(\mu_2 - \mu_1) \quad (4)$$

Given μ_1, known for tissue at any given I_o, analyze the background areas of the given matrix of data to obtain $\ln I_b$. Assuming that the vessel is circular in cross section at its center, find I_c (center intensity) by boundary detection of the minor diameter D and curve fitting the data for all points along D. Substitution of $\ln I_c$ into equation (4), along with d=D, yields the value of μ_2.

$$\mu_2 = \mu_1 + \frac{\ln I_b - \ln I_c}{D} \quad (5)$$

Equation (4) can also take the form:

$$d = \frac{\ln I_b - \ln I}{\mu_2 - \mu_1} \quad (6)$$

In equation (6) d can be assumed to represent a column of opacified blood d units in depth and of cross section 1 x 1 units. Therefore a summation of d over the entire sample matrix will yield the total volume of opacified blood (LVV). Figure 3 demonstrates a typical derived volume curve in comparison with the volume data used for simulation.

The advantage of this method is the minimal processing required to yield the LVV curve. Also, all third

dimension information (inherent in the intensity values) is unaltered by image processing, but rather incorporated into the simple summation calculation of volume.

CONCLUSION

A computer-oriented system has been designed to determine LVV vs TIME. A technique has been developed which provides for a minimum of digital processing and assumptions concerning ventricular shape.

ACKNOWLEDGMENTS

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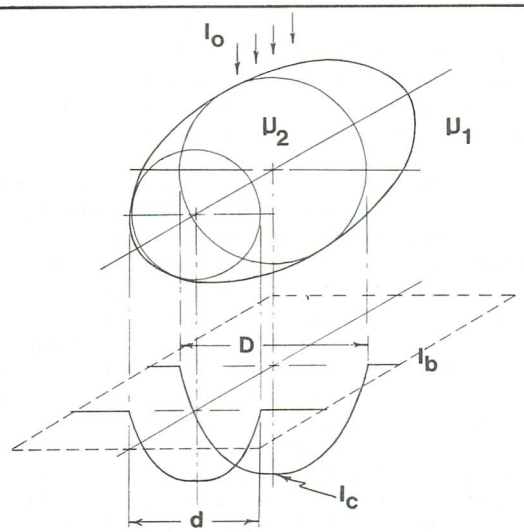

Left ventricle – ellipsoid model

Figure 1

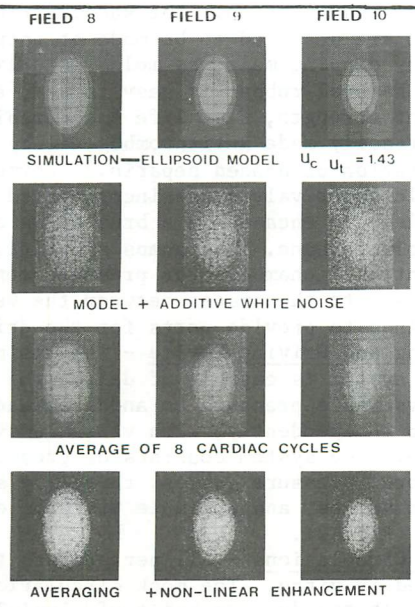

Figure 2

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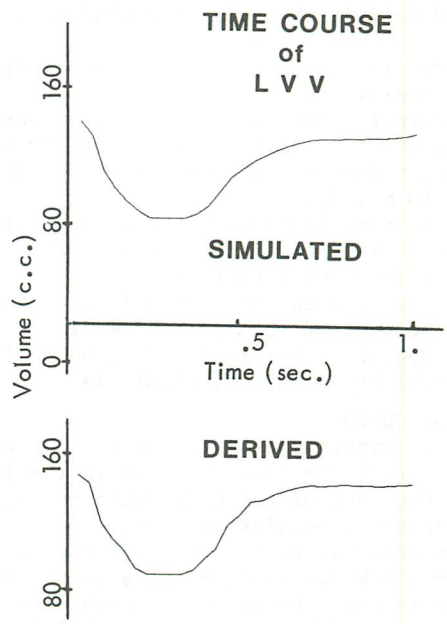

Figure 3