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Fluid Dynamic Study on the Artificial Ventricles by Image Processing Technique

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Introduction

Blood flow characteristics within artificial ventricles are closely related to hematological complications such as thrombosis, hemolysis and calcification. Various techniques of flow visualization are used to study VAD (Ventricular Assist Device) flow patterns. More quantitive investigations are performed with Laser Doppler Anemometer (LDA) and Hot-wire Anemometer and Image Processing Technique[1]. Velocity is the parameter most commonly measured for flow characterization. However, measuring velocity by LDA is great disadvantage that velocity can only be measured at one particular location at a time. Flow pattern images can be also used for the velocity measurement through correlation function, but its image processing is inefficient and expected to be improved.

We have calculated the velocity field of the image captured form the hydrodynamic tester of the prosthetic heart valve (PHV) for investigations of the PHV-induced flow.

From the velocity field distribution, we can expect potential regions inside the artificial ventricle anf near the PHV for hematological complications.

Methods

Flow Visualization

An experiments was performed with the hydrodynamic tester(HDT) which was developed for the evaluation of fluid dynamic properties of the PHV [2]. Schematic diagram of the HDT is shown in figure 1. In order to observe the flow patterns induced by the heart valves, polystylene particles (IRA 904, Amberite ion exchange reison, Rohm & HAss Co., Philadelphia, PA), less than 100 um, was suspended as scatterer and He-Ne laser light source illuminates the transparent acryl oil chamber through a cylindrical lens for the planar irradiation. Flow patterns are taken by Minolta alpha 9000 camera at shutter speeds of 1/250, 1/60, 1/30 sec with the ASA 400 Tri-X film. Still photos are scanned by Sharp color scanner JX-300 and stored in IBM PC and transffered to VAX 11/750.

Image Processing Technique

Artificial ventricular boundary are segmented through iterative process in order to find flow region. From two sequential images, optical flow is calculated by Kalman filtering method which has better performance than existing gradient-based algorithms[3,4,5]. A pixel velocity can be estimated by combining the average velocity of neighboring pixels and a velocity observation at the pixel. Hence we can regard the optical flow estimation problem as two independent parts; the prediction part and the observation part.

Using the generalized least square error estimation (GLSE) in the observation part, the estimated optical part can be more accurate. Futhermore improved gradient measurement techniques are adopted: the extrapolated frame difference (EFD) as temporal gradient instead of frame difference and the motion compensated interframe average for spatioal gradient [6]. The combination of the above meththods has been known to show fast convergence and small steady state error. Vax 11/750 and Gould Image processor IP8500 are used for the calculation.

Results

Figure 2 shows the flow pattern in the artificial ventricle at time passed 7/30 secounds after the begining of diastolic ejection. Large vortex is formed in the center of the artificial ventricule. Figure 3 shows the calculated velocity field represented by arrow vectors. Distribution of high velocity field represented by brightness is shown in figure 4.

Discussion

From the velocity field distribution, potential area for thrombosis formation and cell damage can be known. In the case of high volume flow rates, calculated optical flow may be meaningless because two sequential images have no correlation and the motion constraint is violated. Therefore, comparison of the calculated velocity field with the measured data by other method such as LDA and Hot-wire Anemometer is needed.

In this paper, the feasibility of the image processing application to analysis flow pattern images is tested.

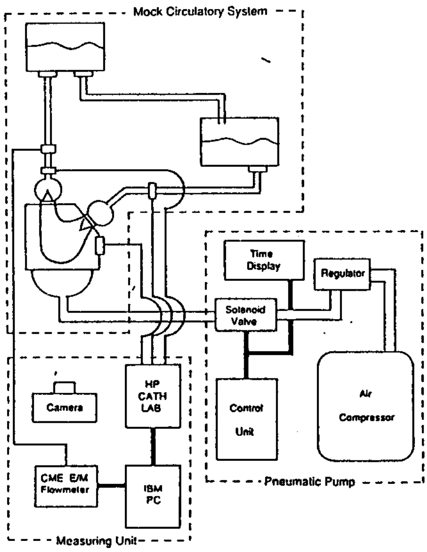


Fig. 1 Schematic diagram of hydrodynamic tester for prosthetic heart valve

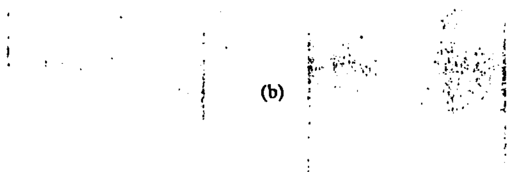
(a)  (b)

Fig. 2 Two sequential images of the flow patterns inside artificial ventricle.
(a) Old image (b) New image

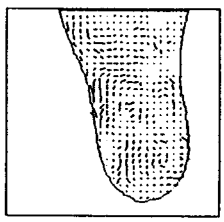


Fig. 3 Calculted velocity field represented by arrow vectors

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Fig. 4 Velocity field distribution represented by brightness fuction.