X-ray PIV 기법을 이용한 혈액유동 특성 해석 및 혈류량 측정

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Quantitative analysis of blood flow and flow rates of whole blood using x-ray PIV technique

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1. 서 론

Circulatory diseases, nearly the leading cause of death in the developing world, put their origin of outbreaks on hemodynamic force[1,2], in the blood vessels of which diameter is in the range of several hundreds micrometer or even larger. The hemodynamic information such as velocity distribution and shear stress[3] has not only been shown to be a critical determinant for early diagnosis of abnormality in circulating system but has also been implicated in vascular remodeling and pathobiology. For investigating the hemodynamics in detail we need to extract quantitative flow information of real and whole blood with no contrast media in high spatial and temporal resolution.

Here we show a new synchrotron x-ray PIV method, which can overcome the limitations in conventional diagnoses. We applied this x-ray PIV method to several opaque flows such as the glycerin flow and blood flow inside an opaque channel using the synchrotron x-ray imaging method based on the phase contrast method[4,5]. In this study, we will assess the feasibility to extract quantitative hemodynamic information on blood flow.

2. 본 론

By applying two consecutive x-ray images of blood flow in a circular tube to the PIV algorithm under the optimum condition mentioned in ref. 5, we could obtain quantitative velocity field of real and whole blood flow without any contrast materials or tracer particles. Inner diameter of the opaque is 2.77 mm and blood flow is injected by a syringe pump at flow rate of 50 μl/min. Exposure time for acquiring each x-ray image is 20 ms. Figure 1 shows a typical streamwise mean velocity profile extracted from the velocity field data along a horizontal line.

At first, from the result of velocity profile of real blood flow without any addictive, we want to suggest most optimum hemorheologic model. So far, we cannot prove which hemorheologic model is most correct because any measurement method couldn't acquire quantitative flow information of real blood invasively with high spatial and temporal resolution. Therefore, this study is first time to compare hemorheologic model with an experimental result. From Fig. 1A, we can see that the experimental data has better agreement with a velocity profile by Casson mode than a typical parabolic velocity profile. This simple result means that the x-ray PIV method will be use to investigate various hemodynamic phenomena in experiment.

Secondly, from the result in Fig. 1B, theoretical parabolic velocity profile based on an input flow rate by a syringe pump is different from the experiment result. When integrating the theoretical velocity profile and the quartic fitting curve based on the experimental data in volume, however, we can fine

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that the values of three dimensional volumes of the theoretical one and the experimental one are almost same in the error range of 0.218 %. From this result, the x-ray PIV method would be suggested as a new diagnosis for measure accurately the volumetric flow rate of blood invasively.

3. 결 론

In this study we demonstrated a noble diagnosis of the synchrotron x-ray PIV method and used this for obtaining quantitative hemodynamic information of real and whole blood without any contrast media. We can verify that the x-ray PIV method can be use to investigate various hemodynamic phenomena in experiment and would be suggested as a new diagnosis for measure accurately the volumetric flow rate of blood invasively.

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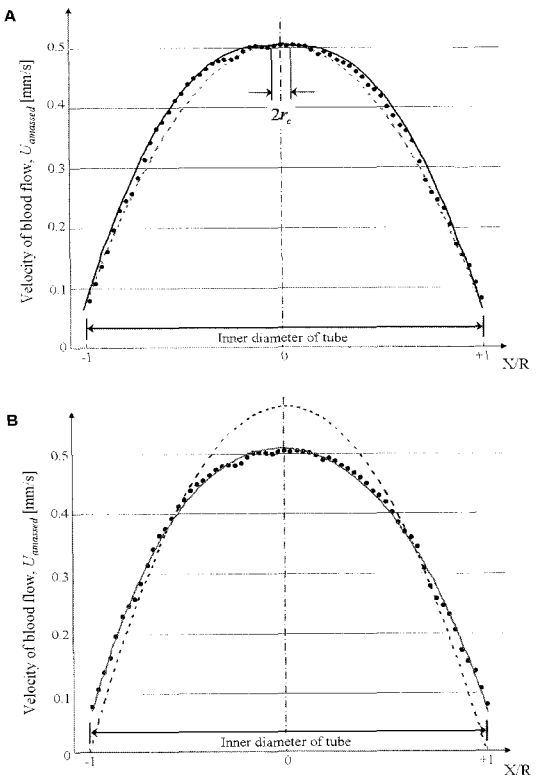

Fig. 1 Streamwise velocity profile extracted from the velocity field data along a horizontal line. A, These velocity profiles are for comparing the experimental data with an optimum hemorheologic model of blood flow. ✱ ✱ ✱: X-ray PIV result in experiment; - - - -: Parabolic fitting curve based on x-ray PIV result; ——: Casson model fitting curve based on x-ray PIV result. **B**, These are for comparing the volumetric flow data measured in experiment with theoretical velocity profiles; ✱ ✱ ✱: X-ray PIV result in experiment; - - - -: Theoretical parabolic curve based flow rate; ——: Quartic fitting curve based on x-ray PIV result.

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