컬러 도플러와 초음파 SIV 기법의 적응형 하이브리드 스킴을 이용한 혈류 측정

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Adaptive hybrid scheme of color doppler and ultrasound speckle image velocimetry for measuring blood flow

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Abstract : Color Doppler (CD) ultrasound imaging system has been commonly used in biomedical field to obtain hemodynamic information. However, it can measure only a single-velocity component, and the measurement results depend on experimental conditions, such as insonation angle and transducer-induced contact compression. In this study, adaptive hybrid (AH) scheme is proposed to enhance the accuracy of conventional CD measurement to acquire the 2D velocity field of blood flows. It can offer the assistance of the velocity field information measured preliminarily using ultrasound speckle image velocimetry (SIV) technique. Consequently, erroneous vectors in the CD results were replaced with the SIV results. The performance of the proposed AH method was validated by varying flow rate and insonation angle. *In vitro* validation experiment with an agarose vessel model demonstrated that the proposed AH method can measure a 2D velocity field with improved accuracy. *In vivo* validation was conducted for venous flow in the human great saphenous vein. The AH scheme allows the accurate measurement of 2D velocity field of blood flow by using the conventional CD method. This novel method can be ultimately utilized to diagnose blood flow in relation to cardiovascular diseases and valve-related varicose diseases.

1. 서 론

Ultrasound imaging (USI) technique has been widely used for the medical diagnosis due to the method's inherent advantages. Color Doppler (CD) method is, especially, useful for measuring flow velocity in the medical field due to the technique's simple expression with hue or color intensity. However, the technique can only display the flow velocity along the direction of the ultrasound beam propagation. In addition, the insonation angle limits the measurement accuracy. The blood vessel and surrounding tissues may be deformed by transducer-induced compression for a large insonation angle condition. [1] Consequently, the CD results are dissimilar depending on the sonographer.

The echocardiography particle image velocimetry (Echo-PIV) technique, vector flow mapping method, ultrasound speckle imaging velocimetry (SIV) method, and conventional medical devices such as MRI were proposed to resolve these technological problems. However, other limitations for their applications occurred simultaneously.

In this study, the performance of conventional CD imaging technique was improved by adopting the adaptive hybrid (AH) of ultrasound SIV method. [2] Then, their performances were examined in terms of flow rate and insonation angle and compared with theoretical results. In vivo validation of the AH method was also carried out for valvular flow in the human great saphenous vein (GSV).

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2. 본 론

2.1. Method

This proposed adaptive hybridization of the ultrasound SIV method and CD technique aimed to reduce erroneous vectors in the CD results. In general, the CD technique has poor spatial resolution but better temporal resolution than that of the ultrasound SIV method. Therefore, measuring the intricate flow patterns and removing the erroneous vectors are difficult to perform. Meanwhile, the ultrasound SIV based on cross-correlation PIV algorithm has better spatial resolution than that of the CD technique. Therefore, the erroneous vectors in the CD results can be removed and replaced by SIV vectors by simple comparison of both techniques for intricate flow structure in a high-velocity gradient region.

2.2. *In vitro* study

The velocity differences between the theoretical values and those from each method were compared to check the flow rate effect. For the inclined flow images, the average difference values of the CD method rose with the increase of flow rate, whereas those of the SIV and AH methods exhibited consistency regardless of the flow rate.

2.3. *In vivo* study

The flow rates estimated at each cross-sectional region were utilized to validate the AH method for in vivo condition by comparing the results obtained by the CD and SIV methods. [3] Both flow rate results obtained from the SIV and CD methods varied depending on the measurement region, whereas those from the AH method remained consistent because of the correction of erroneous vectors on the basis of the adaptive combination of the SIV and CD results.

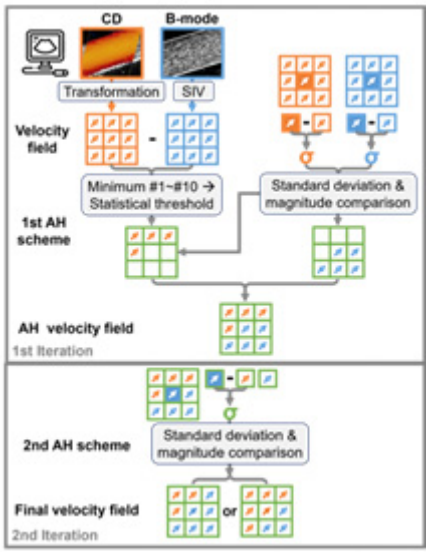

Fig. 17 Flow chart of the AH method

3. 결 론

In this study, a new, compatible, noninvasive USI technique was developed. It can provide accurate 2D blood flow information by adaptively hybridizing conventional CD imaging method with ultrasound SIV technique. Compared with the conventional CD method and other improved CD-based imaging systems, the proposed AH method is more accurate and compatible. This result confirms the best use of the given CD system. Although supplementary validations are needed to apply the proposed AH method for clinical practice, this novel hybrid method can be effectively utilized for diagnosing several circulatory diseases and is especially useful for measuring various valve-related venous flows in the clinical point of view.

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