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Basic study about detection of vascular channels in contrast-enhanced ultrasound images obtained by two-dimensional array probe

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1. Introduction

In ultrasound imaging, a short ultrasonic pulse is transmitted into the body, and the backscattered echoes from various tissues are received to form a tomographic image. For micro-vascular channels with slow flow, the detection from the ultrasound tomographic image is difficult. In this study, contrast-enhanced ultrasound (CEUS) in three-dimensional imaging is examined for the vascular detection. The visualization of vascular channels in the three-dimensional CEUS image potentially enables the stable detection. In this report, microbubbles (MBs) flowing in the micro-channel is visualized in the CEUS image obtained by the two-dimensional array probe, as a preliminary study.

2. Contrast-enhanced ultrasound[1]

MBs, which are comprised gas cores encapsulated in shells, are injected into the vascular channel in CEUS. In the ultrasound image around the channel, the contrast between MBs and surrounding tissues can be increased with higher scattering intensities and the nonlinear responses to the incident ultrasound. Moreover, the contrast is further increased by the elimination of the linear echoes from the surrounding tissues. Therefore, the CEUS image is formed by the nonlinear echoes from the flowing MBs. To eliminate the linear echoes, the multi-pulse transmission technique, which are known as pulse inversion (PI), is typically employed. In the PI procedure, an ultrasonic (positive) pulse is transmitted, and the echoes are received. Then, the amplitude-inverted (negative) pulse is transmitted, and the echoes are received. The nonlinear echoes can be extracted by the summation of the positive and negative echoes.

3. Two-dimensional array probe

In this study, three-dimensional ultrasound image is obtained by the two-dimensional array probe (Vermon, France). The transducers of the probe are 1024 elements. The central frequency and the bandwidth are 7.5 MHz and 60%. The probe is driven by the research ultrasound system Vantage 256 (Verasonics, USA) via the Verasonics UTA 1024-MUX adapter. The transducers are divided to four sub-apertures, and 256 elements are aligned on a 32 × 8 grid with a 0.3 mm pitch in each sub-aperture. There are intervals of 0.3 mm between the sub-apertures. Therefore, the area of the full-aperture of 32 × 32 grid is 9.6 mm × 10.5 mm.

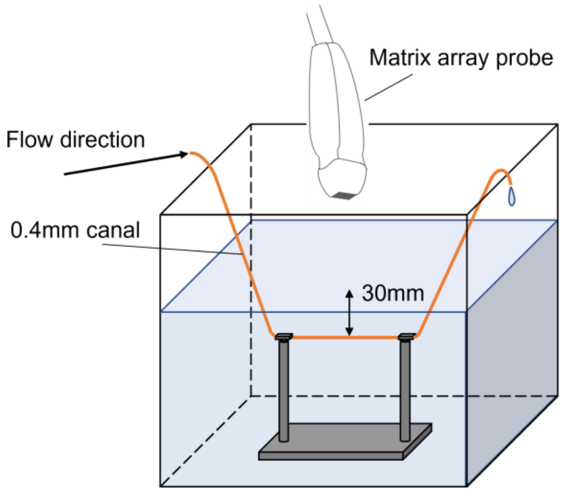

Fig. 1: Experimental setup.

4. Experimental method

The experimental setup in this study is shown in **Fig. 1**. The silicone tube with an inner and outer diameter of 0.4 and 0.5 mm was fixed at a depth of 30 mm in the water tank. A suspension of MBs (Sonazoid, GE Healthcare, Japan) diluted 100 times with ultrapure water was manually injected into the tube. The probe was fixed at the position where the depth of the transducer surface was 3 mm. The tube was aligned in the lateral center of the transducer surface.

In the ultrasound system, only 256 channels are available in each transmission and reception sequence. Therefore, transmission from one sub-aperture and reception by one sub-aperture can be performed in each sequence. For transmission and reception by the full-aperture, 16 sequences of all combinations of 4 sub-apertures were summed in

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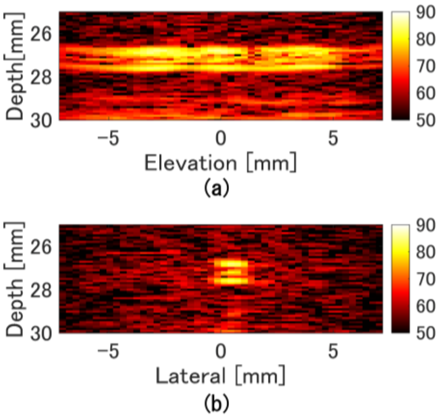

Fig. 2: Echoes after summation in the PI process. (a) long-axis direction. (b) short-axis direction.

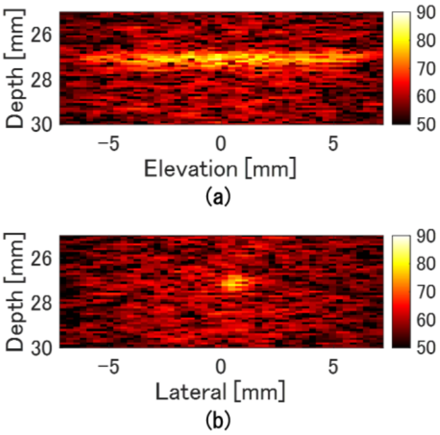

Fig. 3: Echoes after passing through the MTI filter. (a) long-axis direction. (b) short-axis direction.

this study. Therefore, 32 sequences are necessary for full-aperture CEUS.

Two cycles of the sinusoidal wave at 7.815 MHz was transmitted as a plane wave. The applied voltage for the transducer elements were set at 5 V. A total of 10 frames (320 sequences of transmission and reception) were acquired with MBs flowing continuously. The received signals were stored at a sampling frequency of 31.25 MHz. The synthesis of full-aperture echo signals and signal/image processing were performed off-line using MATLAB.

5. Result and discussion

Three-dimensional CEUS images were formed by PI and delay and sum beam forming (DAS). **Fig. 2** shows two-dimensional CEUS images on the long-axis (0.75 mm on lateral position) and short-axis (0.45 mm on elevational position) directions of the tube. Although linear echoes should have been eliminated by PI, the echoes from the upper and bottom surface of the tube have remained around the echoes from MBs. Therefore, the MTI filter, taking the difference between adjoining flames,

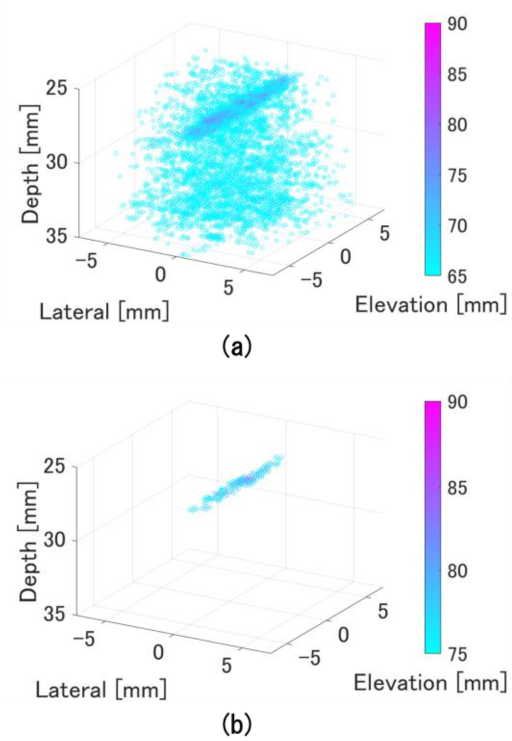

Fig. 4: Three-dimensional CEUS images with the MTI filter in the dynamic range of 65-90 dB (a), 75-90 dB (b).

is employed. Only echoes from stationary object are canceled by the MTI filter. **Fig. 3** shows the filtered two-dimensional CEUS images on the long and short directions of the tube. The echoes from MBs could be extracted by the MTI filter.

Three-dimensional CEUS images with the MTI filter are formed by plotting the pixel intensities. **Fig. 4** shows the images in the dynamic ranges of 65-90 dB and 75-90 dB. In the proposed method, the visibility and sensitivity can be controlled by changing the plotted pixels.

6. Conclusion

In this report, as a basic study for the visualization of vascular channels in the three-dimensional CEUS image, we performed an experiment to observe MBs using a two-dimensional array probe. By using PI and MTI filters, only the MBs component can be successfully plotted in 3D space.

Acknowledgment

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References

1. D. Cosgrove: Eur. J. Radiol. 60 (2006) 324.