2P5-13

Visualization of simulated lymph channels by contrast-enhanced active Doppler ultrasonography using unfocused wave

非集束波を用いた動的造影超音波法による模擬リンパ管イメージング

Katsuya Saito[1†], Kenji Yoshida[2], Masaaki Omura[1], Takuma Oguri[1,3], Naohisa Kamiyama[3], Tadashi Yamaguchi[2]
([1]Grad. Sc. Sci. Eng., Chiba Univ.; [2]Center for Frontier Medical Engineering, Chiba Univ.; [3]Ultrasound General Imaging, GE Healthcare)
齋藤　勝也 [1†], 吉田　憲司 [2*], 大村　眞朗 [1], 大栗　拓真 [1,3], 神山　直久 [3], 山口　匡 [2]
([1] 千葉大院　融合理工, [2] 千葉大　CFME, [3]GE ヘルスケア・ジャパン　超音波製品開発部)

1. Introduction

To visualize lymph vessels, we have proposed a method named contrast-enhanced active Doppler ultrasonography (CEADUS). CEADUS can quantify the translation of ultrasound contrast agents (UCAs) due to the acoustic radiation force by Doppler method. It is assumed that the UCAs is injected subcutaneously into the skin tissue and absorbed into the lymph channels with a stationary fluid or very slow flow. It has been experimentally verified that when ultrasound is irradiated, the acoustic radiation force moves UCAs away from the transducer. In our preliminary study, we succeeded in visualizing a simulated lymph channel in the mimicking skin tissue phantom with high contrast using CEADUS with a single concave transducer.

However, beam scanning in the focused imaging decrease the real time property because CEADUS requires echo data of approximately several hundred mili-seconds per each scan line. We believe that this problem can be improved by high frame rate imaging using plane wave, where all contrast agents in the field of view were exposed to the transmitted ultrasound at the same time. In this report, we constructed unfocused wave transmit/receive system using a commercial ultrasound scanner and attempted pre-experiment of CEADUS imaging with better real time property and a wide field of view.

2. Materials and Methods

2.1. Measurement target

Figure 1 shows the measurement system. To mimic scattering and attenuation characteristics of skin tissue, an agar phantom containing polyamide microspheres with a diameter of 10 µm (ORGASOL, Arkema) at 5 wt% of scatterer concentration. Four cylindrical channels with a diameter of 0.1, 0.3, 0.5, 0.9 mm were formed in the phantom. The channel was set parallel to the others and filled with a suspension of Sonazoid™ as UCAs with number

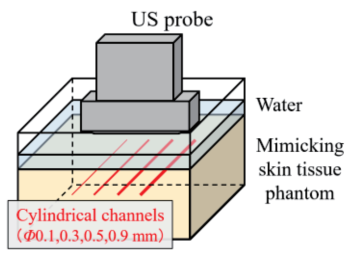

Fig. 1　Experimental system.

density of 1.30×10^{13} bubbles/m^3.

2.2. Data acquisition

Imaging of simulated channels wave was achieved using improved transmit/receive system in a commercial ultrasound scanner (LOGIQ S8, GE Healthcare). In the transmission condition of the linear probe (ML6-15, GE Healthcare), the ultrasound was exposed using the minimum number of elements and the focus was set far away from transducer, resulting in forming an unfocused wave. By scanning with a low line density, frame rate of 454 frames/s was achieved.

The linear probe was located at approximately 20 mm above from channels, and IQ signals were acquired for 0.5 seconds. The conditions for peak value of the negative sound pressure (Mechanical index) was 36, 68, 106, 135 kPa (0.01, 0.02, 0.03, 0.04). The sampling frequency and the quantization rate was 25 MHz and 16 bits, respectively. The measurement was repeated 5 times in the same transmit/receive condition.

2.3. Signal processing

At each scan line, transmitting and receiving was repeated as many as the frame rate. The sequence of received signal was converted to analytical signal. Doppler shift frequency was obtained by applying the same signal processing as the pulse Doppler method. Assuming that the UCAs moved only in the sound propagation direction,

†skatsuya@chiba-u.jp, *kenyoshi1980@chiba-u.jp

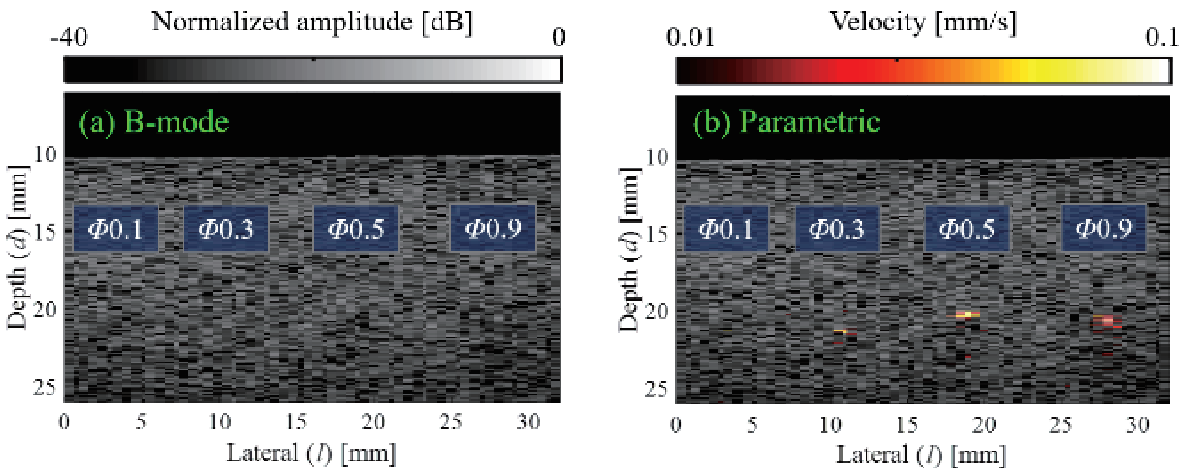

Fig. 2 Example of (a) B-mode image (b) Parametric image with the two-dimensional distribution of UCAs translational velocity when the negative sound pressure is 135 kPa

translational velocity of UCAs was calculated from Doppler shift frequency. Two-dimensional images of translational velocity were acquired by applying the above process to data in all scanning lines.

3. Results and discussions

Figure 2(a) and **(b)** show examples of B-mode image of the channel filled with UCAs suspension and its parametric image with the two-dimensional distribution of the UCAs translational velocity, where the negative sound pressure is 135 kPa, respectively. The displayed color range of the translational velocity is logarithmically compressed. Although the channels were indistinguishable in B-mode image, the locations of channels were detectable with high contrast by CEADUS method. It was shown that the channel with a diameter of 0.1 mm, which is smaller than the spatial resolution, could be detected with the size of several pixels.

The ROI was set manually at each channel locations. The maximum values of the translational velocity in the ROI were measured. **Figure 3** shows maximum translational velocity as a function of the negative sound pressure. It seemed that the translational velocity slightly increased with the increase of the negative sound pressure. On the other

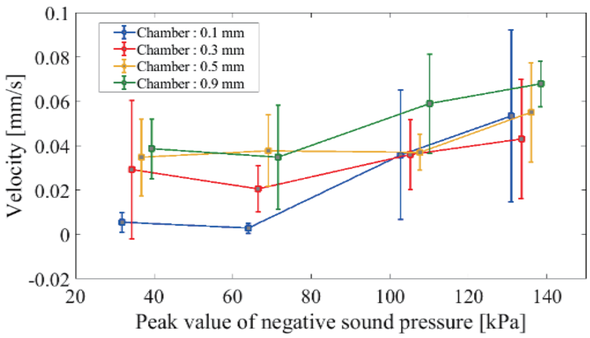

Fig. 3 Relationship between transmitted sound pressure and translational velocity of UCAs. (n=5)

hand, there was few significant effects of channel diameter on the maximum translational velocity.

In clinical situations, we need a countermeasure to the motion artifact due to the clutter echoes. Since peripheral vessel wall of an artery has a velocity of up to 10 mm/s [1], we anticipate that the translational velocity of UCAs should be increased up to one-tenth of the values at least. Our previous experimental data and theoretical prediction indicated that the translational velocity of bubbles was proportional to the PRF where bubbles undergo. PRF is equal to frame rate in high-frame-rate imaging using plane wave. Thus, we expected that detectable translation of bubbles should be induced by increasing the PRF up to ten kHz order. In the future, we will construct this high-frame-rate system with plane wave and improve detection sensitivity of CEADUS.

4 Conclusion

In this report, we conducted the CEADUS method using the unfocused wave transmit/receive system and visualized the simulated lymph channels. We succeeded in detecting the channels with high sensitivity when the negative sound pressure is relatively higher. It is necessary to enhance the translation of UCAs because it is low as 0.1 mm/s or less.

Acknowledgment

This work was partly supported by Terumo Foundation for Life Sciences and Arts, and JSPS Core-to-Core Program, KAKENHI Grant Numbers 19H04436, 17K11529, and the Institute for Global Prominent Research at Chiba University.

References

1. Nagaoka, R. *et al.*: Ultrasonics 55 (2015)