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Effect of BSA Concentration on Cavitation Bubbles in Gel Phantom

ゲル中でのキャビテーション気泡に対する BSA 濃度の影響

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1. Introduction

High intensity focused ultrasound (HIFU) is a noninvasive method for the treatment of cancer but has a problem of a long treatment time in treating a large tumor. During HIFU exposure, cavitation bubbles can be generated by extremely high intensity ultrasound pulses. They can be very useful to make HIFU treatment more efficient because they enhance the heating effect of ultrasound when they oscillate[1)].

In order to investigate a cavitation-enhanced highly-efficient method of HIFU, a polyacrylamide (PAA) gel, in which the behavior of cavitation bubbles can be optically observed in real time, is a useful tool. Bovine serum albumin (BSA) in a PAA gel is known to increase ultrasonic absorption and acoustic impedance of the gel and make its acostic property closer to tissues[2)]. Although the behavior of cavitation bubbles in gel may differ from that in tissue, we observed the behavior in a gel phantom by a high-speed camera and investigated the effect of BSA concentration to analyze the behavier.

2. Materials and Methods

2.1 Experimental Setup

Figure 1 shows a schematic of the experimental setup. The water in the tank was kept at 35°C and continuously degassed. The PAA gel was used as the target. The gels contained four levels of BSA concentration of 0, 7.5, 15, 22.5%. Ultrasound at 1.2 MHz was generated by the array transducer (Imasonic) having 128 equal-area elements, a resonant frequency of 1.2MHz, outer and inner diameters of 100 and 36 mm, respectively, and a focal length of 100 mm. The duration of the ultrasound was 100 μs. Cavitation bubbles were optically captured by a high-speed camera (HPV-2, Shimadzu). In this study, we investigated the difference of the activity of cavitation bubbles caused by changing the focal ultrasonic pressure.

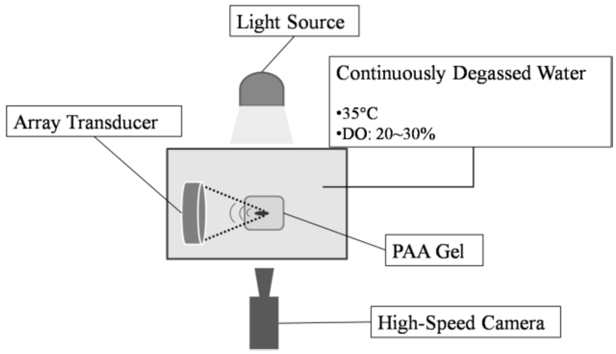

Fig. 1 Schematic of experimental set up.

2.2 Quantitative estimation of cavitation bubble region

Figure 2 shows the region of cavitation bubbles observed by a high-speed camera (left) and the binarized image (right). To quantitatively estimate the area of cavitation bubbles, the image captured by a high-speed camera was binarized, the number of pixels corresponding to cavitation bubbles was counted, and the number was averaged for 4 trials.

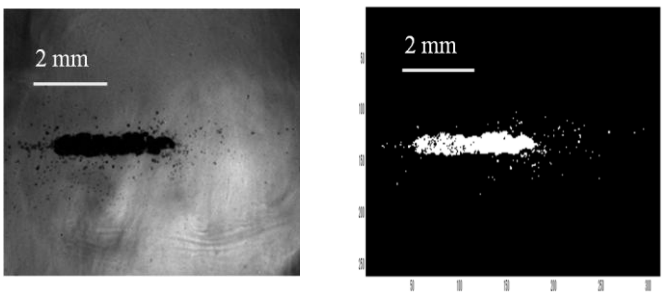

Fig. 2 Cavitation bubble region in high-speed camera observation (left) and the binarized image (right).

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3. Results and Discussion

Figure 3 shows the projected images of cavitation bubble region at a peak to peak focal pressure of 50 MPa. At this focal pressure, no cavitation bubbles were generated in the gel without BSA. In both gels with 7.5% and 15% BSA, cavitation bubbles were slightly detected and the amount of cavitation bubbles with 15% BSA was larger than with 7.5% BSA. The gel containing 22.5% BSA had a large region because cavitation bubbles grew at high ultrasonic intensities. In these experiments, the amount of cavitation bubbles increased as the BSA concentration increased. This suggests that cavitation nuclei increased with the BSA concentration.

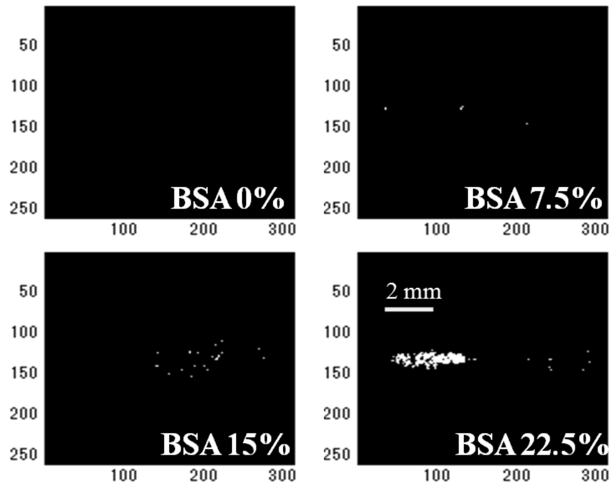

Fig. 3 Binarized image of cavitation bubbles at 50 MPa p-p.

Figure 4 shows the projected area of cavitation bubble region. The amount of cavitation was successfully estimated quantitatively as the projected area of cavitation bubble region.

Figure 5 shows the BSA concentration dependence of the amount of cavitation bubbles at lower focal pressures. The projected area also showed positive dependence on the BSA concentration.

According to the high-speed camera observation, the growth of cavitation bubbles in gels with 7.5% and 15% BSA were often caused by focal pressure above 60 MPa p-p. On the other hand, the cavitation bubbles in the gel containing 22.5% BSA grew at 50MPa p-p. The growth of cavitation bubbles was probably caused by the ultrasonic pressure amplified by the phase-inverting reflection by the cavitation bubble cloud around the focal spot. In the case of a gel with 22.5% BSA, cavitation bubbles were easily generated by a lower ultrasonic pressure. Thus, cavitation bubbles in a gel with 22.5% BSA tended to grow easily because there was more amount of cavitation bubbles.

5. Conclusion

In this study, we quantitatively estimated the amount of cavitation bubbles in a gel phantom successfully by a projected area and found that the amount of cavitation bubbles in a gel had the positive dependence on the BSA concentration. We also found that the focal pressure threshold for causing the growth of cavitation bubbles in a gel probably had the similar dependence on the BSA concentration.

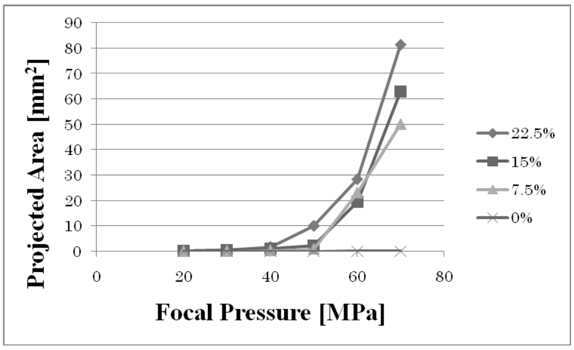

Fig. 4 Projected area of cavitation bubble regon.

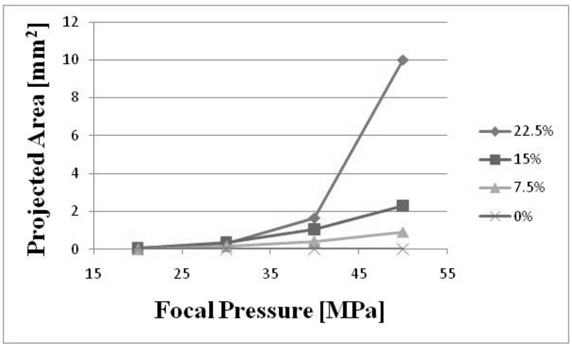

Fig. 5 Projected area of cavitation bubble regon at lower focal pressures.

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