2Pb2-3

Photoacoustic Response of Soft Tube Embedded in Phantom

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1. Introduction

Photoacoustic imaging has created a researh field for in vivo diagnosis because of its high spatial resolution and deep detection depth. Beside the vascularity imaging, researchers extended the application to glucose concentration measurement[1)], blood pulse wave velocity measurement[2)] etc. To further release the potential of photoacoustic technique, plenty of efforts have been concentrated on the smaller target and preciser physical quantity measurements, which were not able to be measured by classical ultrasonic imaging modality. As one of the most important parameters in cardiovascular measurement, quantitative measurement of vascular stiffness is a hot subject. The authors reported an evaluation system of contrast agents for photoacoustic imaging[3-4)], where a thin glass tube embedded in a phantom was used as a sample. By modifing this setup, in this report, we explore a possibility to make a direct measurement of small blood vessel.

As a preliminary experiment, in this report, we investigated the photoacoustic responses of liquid filled in a soft thin tube as a mimicking of blood vessel. The results were compared with the cases for hard tube. Then, we discussed the differences between the photoacoustic and ultrasound images for the soft-tube model by using a pulsed semiconductor laser source and a receiving transducer.

2. Experiment

We prepared a soft phantom of 20 mm in length, 20 mm in width, and 20 mm in height (H00-600J, EXSEAL co.) filled in an uncovered acrylic box as shown in **Fig. 1**. A soft silicon tube (S-0.5×1, As One co.) of 1.0 mm in outer diameter and 0.5 mm in inner diameter was embedded in the phantom horizontally with keeping the distance of 5 mm from the upper surface of the phantom. The soft tube is filled with black ink, which is thought as a primary photoacoustic absorber.

Pulsed light of 340 ns in pulse width and 3 W in peak power was generated using a laser diode at the wavelength of 637 nm (L637G1, Thorlabs), which was driven using a pulsed laser driver (LDP3830, ILX Lightwave) at the repetition rate of 1000 Hz. The light was focused on the axis of the

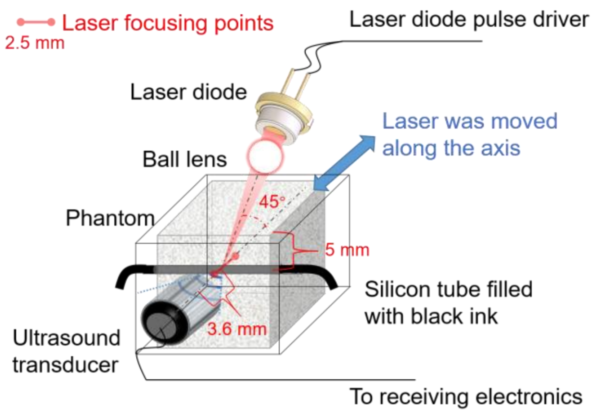


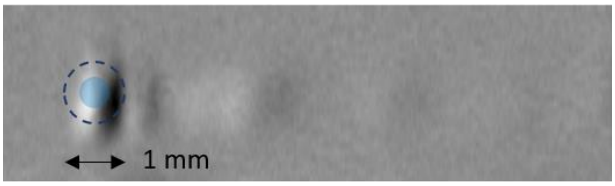
Fig. 1 Experimental setup and sample's geometrical setting.

ultrasound transducer using a ball lens. The angle of incident light was adjusted at 45 degrees to the axis of the transducer, which located in the plane containing the cross section of tube. The laser focusing position was scanned 2.5 mm with the interval of 0.1 mm along the axis of the ultrasound transducer around the silicon tube. Generated photoacoustic signal was received using a non-focused piezoelectric transducer with the center frequency of 5 MHz (5K10I, Japan Probe) located on the side surface of the phantom.

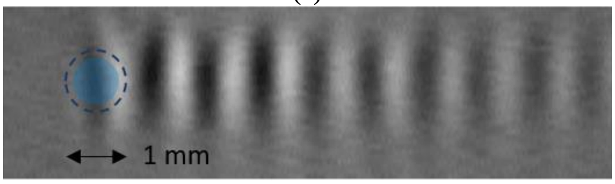
Output electrical signal of the ultrasonic transducer was processed using a low noise amplifier (SA-240F5, NF) with the gain of 40 dB, and then received by a pulser-receiver (5900PR, Panametrics). The setting for the pulser-receiver were 1 kHz, 20MHz, 20 dB, and 54 dB in high pass and low pass frequencies for the filter, attenuation and gain, respectively. The received signals were observed and saved using a digital oscilloscope with a sufficient bandwidth (Wavesurfer 3024z, Teledyne Lecroy).

3. Results and Discussion

Two-dimensional images obtained from the lateral scanning of the light focusing point is shown in **Fig. 2(a)**, where the location of silicon tube is indicated with a dotted circle. We confirmed that that the observed spots were due to photoacoustical excitation, because the sound speed (1150 m/s) calculated from the distance between the tube and



(a)



(b)

Fig. 2 Two-dimensional images in Gray scale representation of photoacoustic signals: (a), results for a silicon tube; (b) results for a glass capillary.

the transducer and the interval between the time origin and the appearance time of the first response is close to the value (1192 m/s) measured separately by the time-of-flight method using the same phantom. In **Fig. 2**, the brighter parts represent higher amplitude while the darker parts represent lower amplitude of photoacoustic signal. It can be observed that a spot overlaps the inner part of the tube clearly. A smaller vague spot following the first spot resulted from the feature of photoacoustic waveform generating in liquids[5)]. We compared the soft-tube-based results with that for a glass capillary. It exhibits strong ringing as demonstrated in **Fig. 2(b).** The periodic cycle is thought to be determined by the inner diameter of the capillary, which could be precisely explained by our previous articles[3-4)].

Secondly, we processed the images by taking the envelope of the waveform in **Fig. 2(a)** along the longitudinal (depth) direction. The results were shown in **Fig. 3**. As a comparison, ultrasonic pulse-echo image using the same transducer is displayed in the same figure. It can be observed that the photoacoustic image is able to clearly show the location of the object for the soft tube, while the hard capillary can hardly be recognized intuitively. Meanwhile, both photoacoustic results have better precision to locate the object in vertical direction than the ultrasound pulse-echo image.

4. Conclusions

In this report, we showed the photoacoustic imaging results for a silicon tube embedded in a phantom. The characteristics were discussed comparing with a glass-capillary. Significant difference between the soft tube and hard capillary was observed. The advantage of photoacoustic imaging was additionally concluded by comparing with ultrasonic pulse-echo method. The results are expected to pave the road for direct vascular measurement in the future.

Acknowledgment

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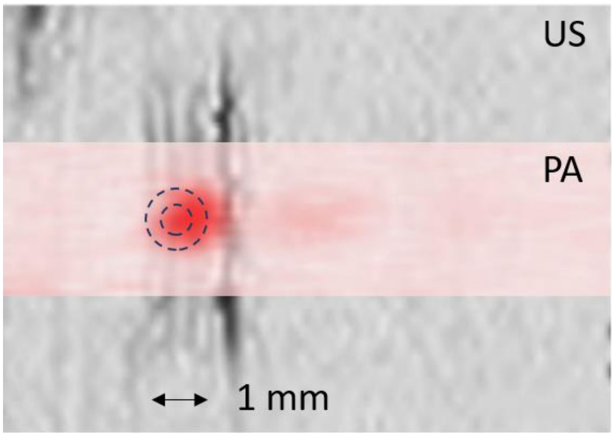
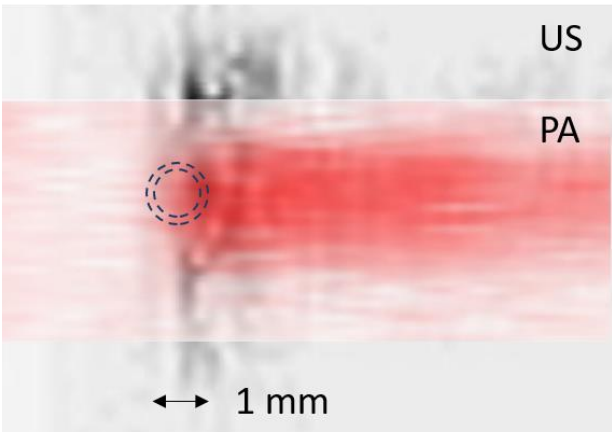


(a)



(b)

Fig. 3 Photoacoustic (red) and ultrasonic pulse echo images (gray) for (a) silicon tube and (b) glass capillary. Dotted circles indicates the locations of soft tube and glass capillary.

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