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Influence by heat transfer of blood flow at temperature rise distribution in tissue phantom caused by ultrasound radiation

超音波照射による生体ファントム内の温度上昇時における血流の熱搬送の影響

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1. Introduction

Ultrasound diagnostic imaging system using ultrasound pulse-echo techniques is characterized as being minimally invasive and having high versatility. Recently, an ultrasound diagnostic imaging system using acoustic radiation force impulse (ARFI) was developed [1)]. ARFI systems have focused ultrasound pulses with a higher power and longer burst time than those in conventional imaging systems. Therefore, it is very important to estimate temperature rise in human body caused by the ultrasound radiation [2)]. The temperature rise in human tissue phantom with bone caused by the ultrasound radiation by both numerical analysis and experiment are reported in previous study [3)].

However, many blood vessels exist in actual human tissue, in addition, one of the function of the blood vessel wss kept the temperature constant in the human tissue. Therefore, cooling effects of the blood flow have to be taken account for the precise estimation of the temperature rise in the human tissue. We have been reported cooling effect of the blood vessel by the numerical analysis under the HIFU condition by numerical analysis[4)]. The cooling effect of the blood vessel is examined by changing flow velocity in the blood vessel. In this stduy, the temperature rise caused by focused ultrasound radiation in the tissue phantom with the water flow are measured to estimate the effect of heat transfer by water flow.

2. Experiment setup

The schematic diagram of measurement system are shown in **Fig. 1**. Sound source was a concave focused transducer: frequency 1 MHz(PAL, PA710), diameter 43 mm, focal length 55.0 mm in water. Radiation condition was as follows: sound intensity I_{SPPA}=180 W/cm^2, duty ratio 20 % (Radiation time 20 μs), total radiation time is 300 s. To estimate the temperature rise caused by ultrasound radiationin in a soft human tissue, the manufactured the tissue phantom is made of water, agar, glycerin, and other materials. The shape of phantom was fiited a surface of concave focused transducer as like to Fig. 1. The phamtom splitted two parts to measure the temperature rise on ceter plan in phantom. 2-D temperature rise distribution was measured by infrared camera (NEC Avio, R300). Mimicking blood and blood vessel were made by water and silicone tube, resepectiviltiy. The inexternal diameter and tihckness of silicone tube were 10.0 mm and 0.3 mm. Cooling effect of blood flow was ensured by changing flow rate of water from 0 to 500 ml/min. Water flow was controlled by roller pump (Cole-Parmer, 7553-71).

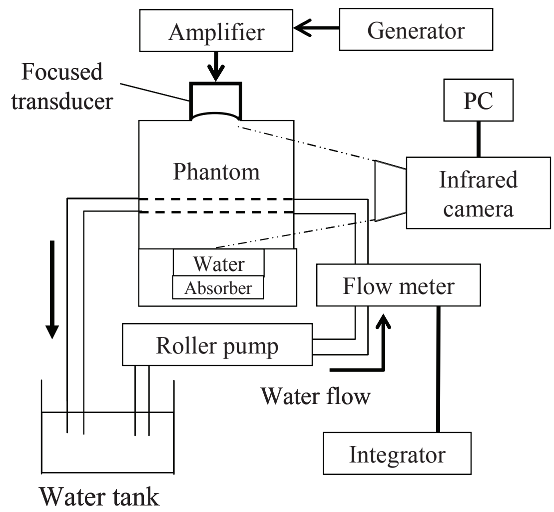

Fig. 1 Schematic diagram of measurement system.

3. Measurement result

Figure 2 (a) and (b) show the measurement result of temperature rise in center plane of tissue phantom at flow rate 0 ml/min and 250 ml/min. As shown in Fig. 2(a), temperature of the phantom rose near axial propagation direction. Maximum value of temperature rise appeared about 4 ºC at focal point. On the other hand, as shown in Fig. 2(b), maximum value of temperature rise at focal point was lower than in case of Fig. 2(a), because water flow cooled generating heat in tissue

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phantom caused by ultrasound radiation. **Figure 3** shows the temperature rise distribution on central axis when flow rate was changed from 0 ml/min to 500 ml/min. As in lower flow rate under 200 ml/min, maximum value of temperature rise was became decrease. However, maximum value of temperature rise kept about 3.5 º C when flow rate was over than 250 ml/min.

4. Estimation of the heat transfer by water flow

To estimate the effect of heat transfer by water flow, the temperature depression near focal point was calculated from measurement results. Temperature depression was defined as the difference value between the results of temperature rise without water flow and the results of temperature rise with water flow. ROI for obtaining the average of temperature depression near focal point set on 20 mm×20 mm, as show in **Fig. 4**. The center of ROI was a distance from center of sound source at 55 mm. The distance of center position was equal to the center of silicone tube. **Figure 5** shows the relationship between temperature depression and flow rate. Temperature depression saturated about 0.7 ºC at water flow over than 200 ml/min. the cause to be saturated is expected that water temperature always kept constant for an early speed of water velocity. At the results of lower flow rate, temperature depression was proportional to flow rate. As a result, it was clearly shown that relationship between temperature depression and flow rate.

4. Conclusions

In this study, to estimate the effect of heat transfer by blood vessel in human tissue, the temperature rise caused by focused ultrasound radiation in the tissue phantom with the water flow are measured. Under the condition of by changing the water flow using focus transducer, temperature depression was observed near maximum position of temperature rise. In future work, the temperature rise in the tissue phantom with the water flow is measured by changing radiation power by focused transducer.

References

1. K. Nightingale and M. Palmeri: IEEE Int. Ultrasonics Symp. Tutorial 6C (2009).
2. M. Tabaru, T. Azuma and K. Hashiba, Jpn. J. Appl. Phys. **49**, 07HF09 (2010).
3. S. Shimizu, K. Fukasawa, T. Tsuchiya, and N. Endoh: Acoust. Sci. & Tech., **36** (2015) 178-181.
4. S. Shimizu, T. Tsuchiya, K. Fukasawa, Y. hatano, and N. Endoh: Jpn. J. Appl. Phys. **54**, 07HF22 (2015).

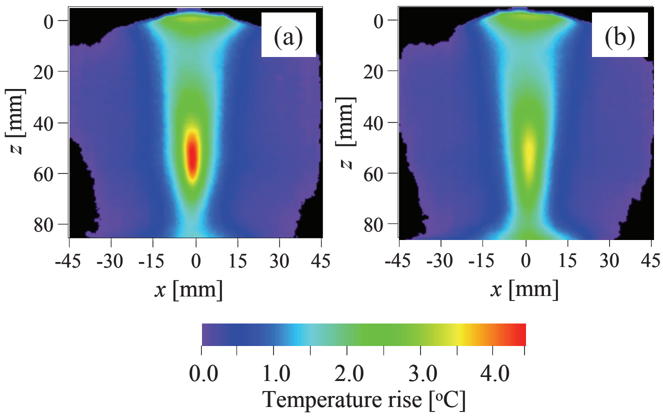

Fig. 2 Measurement result of temperature rise in center plane of tissue phantom, (a) is 0 ml/min (no flow), (b) is 250ml /min.

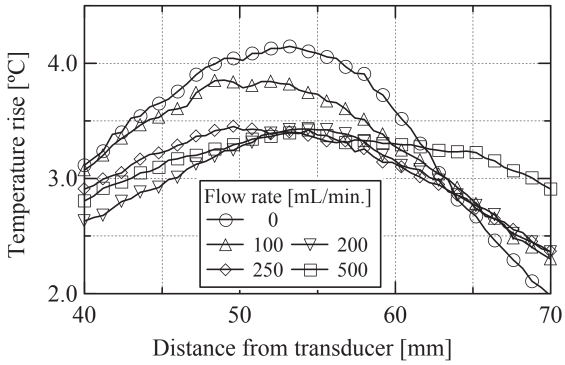

Fig. 3 temperature rise distribution on central axis.

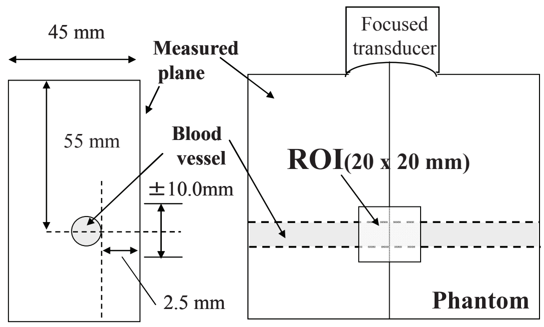

Fig. 4 ROI for obtaining the temperature depression.

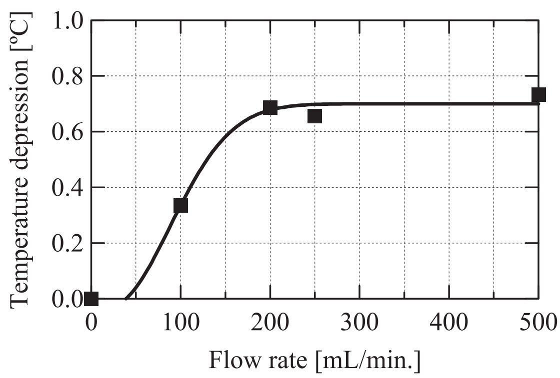

Fig. 5 Relationship between temperature depression and flow rate.