2P5-9

Proceedings of Symposium on Ultrasonic Electronics, Vol. 35 (2014) pp. 321-322
3-5 December, 2014

Distribution of temperature elevation caused by moving HIFU transducer

Jungsoon Kim[1], Jihee Jung[2], Moojoon Kim[2†], Eunghwa Lee[3] and Ilkwon Lee[3], Kanglyeol Ha[2]
([1]Tongmyong Univ., Korea; [2]Pukyong National Univ., ; [3]Chungwoo Medical Ltd., Korea)

1. Introduction

High intensity focused ultrasound (HIFU) for dermatology stimulates subcutaneous tissue, while moving its position[1)]. Generally, the transducer is small-sized, less than 20 mm in diameter, and the frequency is higher than 4 MHz, which is comparatively high. The focal point of the HIFU transducer is located in the subcutaneous of skin, and the heat caused by ultrasound stimulates the tissue of the subcutaneous layer while the transducer moves on a linear path. It produces the results that the skin regains the elasticity by its totipotency[2)]. It is very important to analyze and estimate the effect on the human tissue, caused by ultrasonic energy radiated from the HIFU transducer for designing, and operating the HIFU for dermatology[3)]. Many studies on the heat elevation effect caused by ultrasound in the human tissue or the tissue mimicking phantom have been reported[4,5)]. However, the level and range of temperature elevation in human tissue when the focused ultrasound is radiated while moving its position are different from those when radiated in a fixed position. In this study, a small-sized HIFU transducer and a tissue mimicking phantom for temperature visualization are fabricated. The transducer radiates ultrasound through the acoustic window of a cartridge into the phantom while it moves on the surface of the phantom in a constant speed using a stepping motor. The tissue mimicking phantom is made of carrageenan and thermochromic film is sandwiched to visualize the temperature elevation effect, and the change of temperature distribution in the phantom is examined with different ultrasonic energy and speed of the transducer.

2. Experiment

Figure 1 shows the experimental setup to visualize the temperature elevation in tissue mimicking phantom caused by the ultrasound radiated from moving HIFU transducer. A small HIFU transducer which is mounted in a housing filled with water can move with the speed of 0.03 m/s by a linear stepping motor. The moving range of the HIFU transducer is around 25 mm, and the radiated surface of the transducer has the acoustic window of 0.2 mm thickness. This transducer stops at the given interval in whole moving range, and radiates the focused ultrasound of 4.5 MHz resonant frequency during certain duration. Both the curvature and aperture of the HIFU transducer are 18 mm, the focal position of HIFU is located at 4.5 mm from the outer of the acoustic window. The tissue mimicking phantom was fabricated using 10% carrageenan gel, which has very high transparency and similar acoustic characteristics to human tissue. The acoustic window side of HIFU transducer was attached on the tissue mimicking phantom and the focused ultrasound from the transducer was then propagated in the phantom. Here, to visualize the temperature elevation effect caused by the ultrasound, the thermochromic film was put on the acoustic axis of the transducer[5)]. The change of temperature distribution within the phantom was observed at each of critical temperatures by using the thermochromic films of critical temperature of 40 °C, 50 °C, 60 °C and 70 °C. The discolored area on the thermochromic file caused by temperature elevation effect of ultrasound was recorded by high resolution digital camera and then the image was analyzed with a digital image processing. Temperature elevation effect was investigated with the radiation energy from the transducer, and the moving step of the transducer.

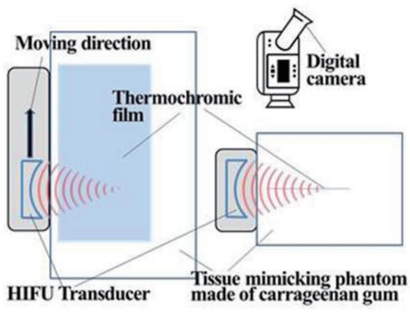


Fig. 1 Schematic of experiment.

3. Results and discussion

The resonant frequency of the HIFU transducer was 4.5 MHz in measurement. To obtain the electro-acoustic efficiency, the impedance was measured with the acoustic load and without it, respectively. From the impedance, the electro-acoustic efficiency was obtained around 65%. The acoustic speed, the attenuation coefficient, and the

kimmj@pknu.ac.kr

density of the fabricated carrageenan gel were 1518 m/s, 0.47 dB/cm/MHz, and 1040 kg/m^3, respectively in measurement. From those results, it is confirmed that the acoustic characteristics of the gel are similar with those of human tissue. The HIFU transducer in a cartridge stops at the regular intervals and radiates ultrasound beam while moving on a linear path. The moving speed of the transducer between the intervals was 0.03 m/s. We examined the temperature elevation effect caused by ultrasound increasing the interval by 1 mm from 1 mm to 5 mm. The acoustic power and duration time of the ultrasound changed as shown in **Table 1**. The discolored area caused by ultrasound in the phantom was recorded with digital camera when the HIFU transducer was driven with the conditions.

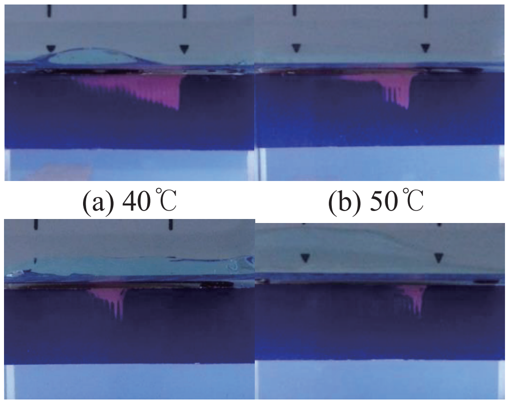
Table 1 Driving condition of HIFU transducer

Acoustic power (W)	Irradiation time (s)	Acoustic energy (J)
6	0.011	0.065
11	0.017	0.195
14	0.023	0.325
18	0.033	0.585
21	0.037	0.780

Figure 2 shows the results from the case with 1 mm interval and 0.78 J acoustic energy. From these results, we can see that the discolored area caused by temperature elevation is distributed widely even after the moving transducer passed because there is the residual energy in the phantom. However, as the critical temperature of thermochromic film becomes high, the discolored area becomes narrow as shown in Fig. 2(b) ~ (d). The temperature distribution in phantom can be estimated by using multiple thermochromic film with different critical temperature. The discolored areas were measured for different interval and acoustic energy, and the results for each critical temperature are shown in **Fig. 3**. From these results, the discolored area increases as the acoustic energy increases and as the interval decreases. The area also decreases rapidly when the critical temperature becomes high. The optimum driving condition for appropriate temperature elevation and range could be obtained from these results, and it would be important information to secure the safety and efficiency of operation.

4. Summary

In this study, in order to examine the heat stimulus caused by HIFU transducer for dermatology on human tissue, the temperature elevation in the tissue mimicking phantom was visualized when the ultrasound was radiated while a small sized HIFU transducer moved on the surface of the phantom. As the results, the temperature elevation degree and range could be obtained for different acoustic energy and moving interval when the HIFU transducer moved on linear path. Using suggested method, the accumulated thermal energy distribution in human tissue caused by ultrasound can be estimated non-invasively, and it would provide important information to design the transducer and to estimate remedial value.



(a) 40℃ (b) 50℃

(c) 60℃ (d) 70℃

Fig. 2 Temperature elevation caused by moving HIFU transducer for different critical temperature. Moving interval: 1 mm, Acoustic energy: 0.78 J.

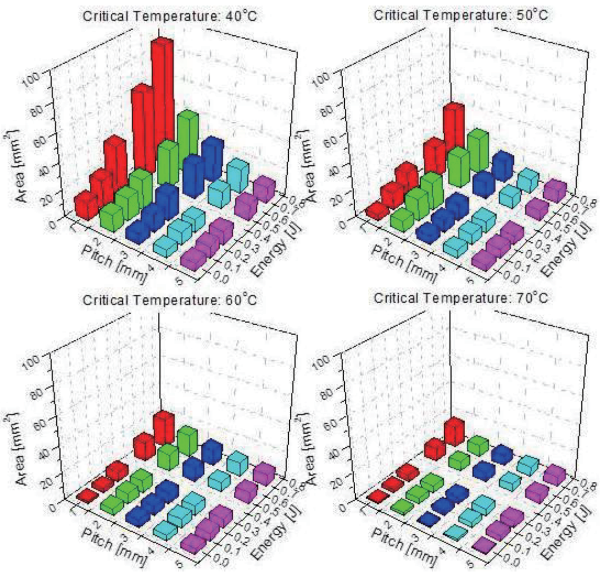


Fig. 3 Discolored area change with acoustic energy and moving interval

Acknowledgment

This work was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2012R1A1B5001048). This work was also funded by Korea Industrial Complex Corp., 2013.

References

1. J. MacGregor, and E. Tanzi: SCMS **32** (2013) 18.
2. Alam M, White LE, Martin N, et al.: J Am Acad Dermatol. **62** (2010) 262.
3 Chan NP, Shek SY, Yu CS, et al Lasers Surg Med. **43** (2011) 366.
4. J. Wu and G. Du: Ultrasound in Medicine and Biology **16** (1990) 489.
5. J. Kim, M. Kim, and K. Ha: J. Appl. Phys. **50** (2011) 07HC08.