3P5-18

Proceedings of Symposium on Ultrasonic Electronics, Vol. 30 (2009) pp. 557-558
18-20 November, 2009

Coagulation of Large Region by Creating Multiple Cavitation Clouds for HIFU Treatment

強力集束超音波治療法におけるマルチキャビテーションを利用した広範囲焼灼

Yuta Inaba[1‡], Shin Yoshizawa[1] and Shin-ichiro Umemura[1] ([1] Tohoku Univ.,)
稲葉脩太 [1‡]，吉澤晋 [1]，梅村晋一郎 [1] （[1] 東北大）

1. Introduction

HIFU (High Intensity Focused Ultrasound) is attracting attention as a minimally invasive therapeutic modality, but it has a problem of long treatment time. To improve its treatment throughput,[1-3] we developed a method to coagulate a large region at one time utilizing multiple clouds of acoustic cavitation and named it as "Triggered HIFU". Ultrasonically induced cavitation is the primary cause of sonoluminescence and sonochemical reactions and also known to enhance tissue heating when it is generated in the focal region of HIFU.[4] The research is performed on triggered HIFU to improve the coagulation throughput using non-spherically focused ultrasound waves right after generating cavitation clouds.

Cavitation clouds were generated at three positions at the same time with high intensity focal ultrasound pulses (Triggering Pulse) by changing the focal distance of an annular array HIFU transducer. The tissues in the vicinity of the cavitation clouds were coagulated simultaneously with the non-spherically focused ultrasound waves at a relatively low intensity (Heating Pulse), and the coagulating performance of triggered HIFU was confirmed.

2. Materials and methods

We controlled a multifunction generator (WF1974, NF Corp.) with a PC to generate waves and change them each millisecond. The waves were input to RF amplifiers (100A2, E&I) to drive each element of the transducer. The array transducer (ImaSONIC) had six annular elements with a central frequency of 1.0 MHz. The outside and inside diameters were respectively 100 and 46 mm, the radius of curvature was 100mm, and each element has an equal area.

A thermal coagulation experiment with chicken breast tissue was performed with the transducer in degassed water (DO 50~60%). First, a triggering pulse was irradiated for 100μs to each focal point while varying the focal distance sequentially as 110mm, 100mm, and 90mm by changing the phases of the waves from the transducer elements. This cycle was repeated for 10 times (total irradiation time: 1.0ms for each focal point). Right after these cycles, a heating pulse was irradiated with an elongated focus covering the all three focal points. The focus was elongated by non-spherical focusing. The focal acoustic field was calculated with linear approximation and shown in **Fig. 1**. The ultrasound intensity and exposure time are shown in **Table 1**. In Fig.1, point (0, 0) is the geometric focal point of transducer, positive direction of x axis is the direction of ultrasound propagation.

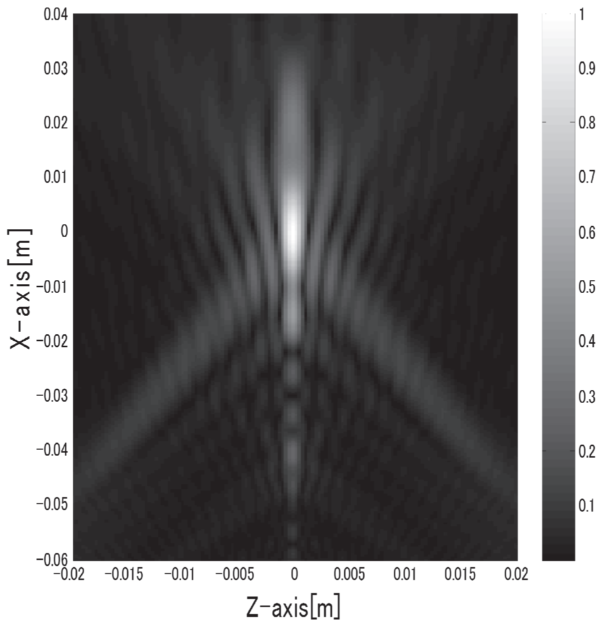

Fig.1. Numerical result of HIFU pressure field

----

y_inaba@ecei.tohoku.ac.jp

Table 1 Ultrasound intensity and exposed time

	Acoustic Power[W]	Exposed Time
Triggering Pulse	258.6	1.0[ms]
Heating Wave	74.0	10[s]

3. Result

The result of the coagulation experiment of chicken tissue with triggered HIFU and the coagulation volumes are shown in **Fig.2** and **Table 2**, respectively. The coagulation spots from the right to the left correspond to the focus distance of 90mm, 100mm, and 110mm, respectively. The width of coagulation region became wider as the focal distance increased.

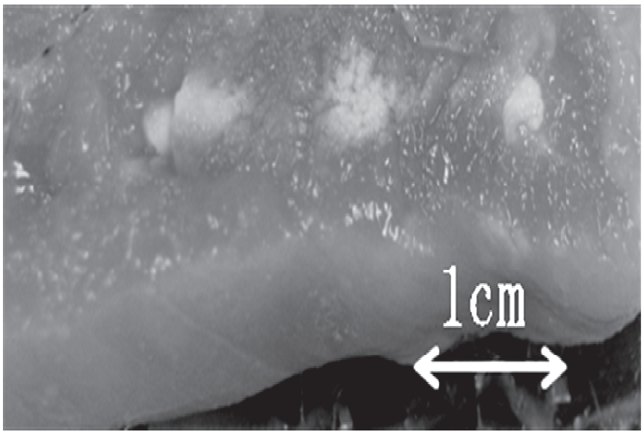

Fig.2. Annular array HIFU coagulations of chicken

Table2 Coagulation volume

Focal Distance[mm]	90	100	110
Coagulation Volume[cm^3]	0.033	0.057	0.061

4. Discussion

Multiple coagulation spots were produced simultaneously with heating waves by creating multiple cavitation clouds with in prior plural triggering pulses. The result in Fig.2 indicates that the cavitation clouds produced by the triggering pulses had survived until the heating waves reached the focal spots to enhance its effect. The multifunction generator needed 20 ms for changing the phase and restarting the output of the waves. Therefore, it took about 63 ms in total from sending the first triggering pulse until sending the heating waves. It takes about 0.1 second for a microbubble with a diameter of several micrometer to extinct.[5] Furthermore, a microbubble can be stabilized easily in media with many impurities like chicken tissue, which will provide an even longer extinction time. Therefore, it is reasonable to have such results as shown in Fig.2. A rather arbitrary shape of coagulation volume may be formed by controlling the focal positions of the triggering pulses as well as the focal shape of the heating waves. Heating wave was focused non-spherically to elongate the focal region in the direction of propagation. The pressure peaks were created at focal distances of 110mm and 100mm, considering the attenuation of the ultrasound in the tissue so as to heat the tissue in all of the three focal positions simultaneously. The reproducibly of the observed effect will be further improved by optimizing the triggering pulse intensity and sequence as well as the non-spherical focusing of the heating waves.

5. Conclusion

It was reported that cavitation clouds generated at focal positions by triggering pulses can enhance coagulation with heating waves producing a large coagulation volume simultaneously. The result suggests that the HIFU treatment time can be significantly shortened by employing the proposed method.

6. Acknowledgment

We would like to thank Prof. Yoichiro Matsumoto (The Univ. of Tokyo) for supporting us to use the annular array transducer.

7. References

1. S. Umemura, K. Sasaki.et. al., IEEE Ultrason. Symp.Proc.(1999)
2. S. Umemura, K. Sasaki.et. al., IEEE Ultrason. Symp.Proc.(2000)
3. Umemura S, Kawabata K.et. al., (2005) IEEE TransUltrason Ferroelectr Freq Control 52:1690–1698.
4. L.A.Frizzell, In Ultrasound. K. S. Suslick,Ed; VCH Publishers: Weinheim.Germany, 1899: Chapter 4. pp 287-301
5. Neppiras EA. Acoustic cavitation. Phys Rep 1980; 61: 159-251