2P5-1

Study on method for estimating focal pressure by detecting variation in speed of sound
音速変化検出による集束超音波の焦点圧力推定手法の検討

Yutaro Tsujimoto[1†], Kazuya Shimizu[1], Takashi Azuma[2], and Shu Takagi[1] ([1]School of Eng., The Univ. of Tokyo, [2] School of Med., The Univ. of Tokyo)
辻本雄太郎 [1†], 清水和弥 [1], 東隆 [2], 髙木周 [1] ([1] 東大院 工, [2] 東大院 医)

1. Introduction

Recentry a thermal dose in ultra sound theraphy are measured with MRI (Magnetic Resonance Imaging) for high accuracy HIFU (High Intensity Focused Ultrasound) therapy . However there are not any method for moinitoring the focal pressure of HIFU in situ of a treatment without temperature increase. Therefore we tried to construct measuring method for sound speed distribution with USCT (Ultra Sound Computed Tomography) in order to estimate quantitative focal pressure on the basis of sound speed dependency to pressure. To attain these contents, we measured variation in sound speed due to pressure fluctuation and evaluated phase shift effect of treatment beam. Monitoring pressure of HIFU will be useful for intracranial HIFU theraphy without temperature increase, for example deliverability improvement of the drug by vasopermeeability increase at Blood Brain Barrier, which will lead to development of Alzheimer's disease treatment.

The method for getting distribution of physical parameter in biological tissue was proposed by Sato, which use two types of ultrasound, one was for causing the biological process and the other was for detecting it. After that several method have been studied [1]. We tried to apply this method to manage accuracy of HIFU therapy. Ultra sound is likely to be affected by individual skull structure, so it is important to grasp focal pressure and the change in temperature during treatment.

tsujimoto@fel.t.u-tokyo.ac.jp

2. Experiments and Analysis Method

We used two types of ultrasound, one is a HIFU intended for treatment, the other is a pulse wave for measuring pressure fluctuation. In order to measure it, we tried to detect arriving time difference of wave as a variation in sound speed as caused by pressure fluctuation at wave propagation medium.

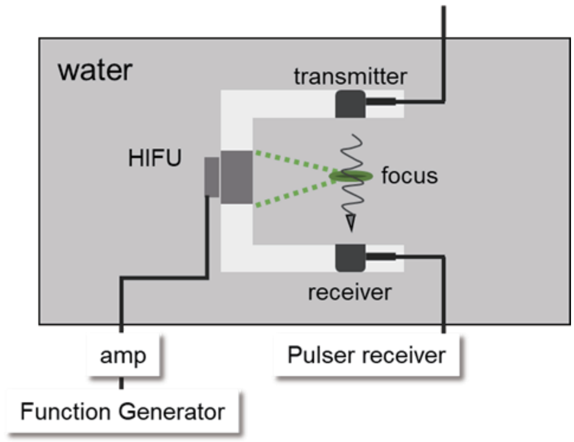

Fig.1 Configuration of equipments

2.1 Relation between Sound speed and Pressure

The relation between pressure fluctuation at the propagation medium and propagation velocity is shown as the following equation considering nonlinearity in medium density and pressure.

$$c = c_0 + \left(\frac{B}{2A} + 1\right)\frac{\Delta p}{c_0 \rho_0} \qquad (1)$$

Here, c is sound speed at given medium, c_0 is sound speed at static pressure, B/A is nonlinearity parameter, Δp Pa is pressrue fluctuation and ρ_0 is density of medium at static pressure [2].

2.2 Experiments Method

We performed two types of experiments. First we compared arriving time difference of wave between under HIFU irradiating and not irradiating. Second the phase of HIFU was changed to 8ways and arriving time of wave was observed.
Frequnecy of HIFU is 2.25 MHz. We irradiated continuas wave in the former and irradiated 20 cycles burst wave in the latter. Experimental parameters are listed in Table I .
It is possible to measure the pulse wave which pass through the focal point several times because the surface of transducer reflects propagating pulse wave.
Using this, accumulated arriving time difference was observed, that is, even though focal size was small, variation in sound speed was possible to be measured. And while pulse wave is passing through the focal point, focal pressure alternately repeats positive and negative value, therefore changing the phase of HIFU which reach the focal point simultaneously with pulse wave can control how the focal pressure changes.

Table I measurement parameters

Focal length (HIFU)	39.5 mm
Aperture (HIFU)	38.1 mm
Pulse wave frequency	2.6 MHz
Diameter (pulse wave)	18.9 mm

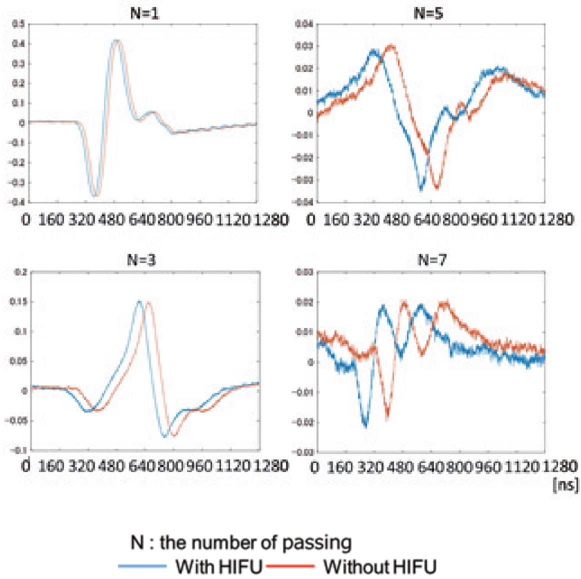

Fig.2 comparison between two pulse waves

3 Results and Discussion

First we compared arriving time of pulse wave. Fig. 2 shows 4 patterns graphs. Each number of pass is 1, 3, 5, 7. As the number of passing the focal point is increasing, arriving time difference of wave for measuring got larger. For example, the difference after passing 3 times was -48.6 ns, on the other hand theoretical values is -39.3 ns. There is a discrepancy of 19.1% between the theoretical value and the actual measured value. When the number of reflections was increasing, accuracy was deteriorating due to attenuation.

At second experiment, we changed the phase of HIFU when passing through the focal point in 8ways and compared the degree of variation in sound speed. In the 8patterns the biggest difference was 4.4 ns.
So it can be important to consider the phase of HIFU for calculating the acurate focal pressure.

4. Conclusion

In the study, we observed pulse wave which pass through the focal point and variation in sound speed. Using this method can be helpful for calculating focal pressure. Also, the experiment was conducted with changing the phase of HIFU.

In further studies, we will analyze the effect of controlling the phase of HIFU and focus size on accuracy of this measuring method. And we will optimize the experimental system so that pulse wave pass through the focal point from several directions. Several wave data from a lot of transducers will be helpful to calculate the accurate focal pressure.

References

1. I. Sato and Ichida: Jpn. The Journal of Acoustical Society of Japan. **39** (1983) 521.
2. A T J Hayward: Br. J. Appl. Phys. **18(**1967) 965