1. Introduction

High intensity focused ultrasound (HIFU) treatment is one of the non-invasive treatments. Congenital diaphragmatic hernia (CDH) is a severe fetal disease. Most popular treatments for CDH is fetal endoscopic tracheal occlusion (FETO). For this treatment, a small balloon is placed in the trachea for several weeks. However, the balloon must be removed before birth to prevent the newborn’s suffocation. The state of the art for the balloon removal is the needleling with the endoscopy or the ultrasound guide. We aim to increase non-invasively balloon rupture by HIFU and show its feasibility using animal model.

Fig. 1 shows the schema of our animal experiment. A sacrificed rabbit is the model for the fetus, and was placed supine with the water tank filled with the degassed water, which simulates the uterine cavity and the amniotic fluid. The balloon was placed in the trachea, between vocal cords and sternum, filled up with the mixture fluid of nanodroplets (PCND-US-100LG, HITACHI, Japan) and microbubbles (Sonazoid®). The nanodroplets are gasified by HIFU irradiation.

The HIFU transducer (IMASONIC, France) is doughnut type and specially designed. An imaging probe was mounted at the center of HIFU transducer. The measured beam diameter at the focus is 2 mm. The focus range is 15 mm. The focal length is 120 mm. Intensity (Isata) is 3 kW/cm² (CW). Operating frequency is 1 MHz. The irradiation time of HIFU is 5 to 30 seconds. The inflated balloon and ruptured balloon are shown in Fig. 2. The inflated balloon was about 6 mm in diameter, and 20 to 30 mm in length. Because we give the first priority to the balloon rupture and HIFU irradiation was continued until skin burn, which often occurred. In Fig. 3(a), the skin burn is the same size as the spot size of HIFU beam, which is acceptable. However, there is larger damage compared with the spot size of HIFU in Fig. 3(b). In this report, we consider the mechanism of the large skin damage using the beam profile of HIFU.
2. Method

The profile of acoustic pressure was superimposed on the photo of skin burn (Fig.3(b)). The profile was calculated with the following assumptions. (1) The transducer of HIFU was approximated with point sources. (2) The HIFU transducer transmitted CW, and we evaluated the acoustic pressure during the steady state. (3) The non-linearity of water was not considered.

The distance between the focus of HIFU and the skin was measured from the ultrasound image.

3. Results / Discussion

The simulation result of the HIFU beam is shown in Fig. 4. The beam diameter at the focus is 3mm. The focus range is 15mm. These values are acceptable to compare with the measured values. Fig. 5 shows ultrasound image of the treatment area. The balloon and HIFU beam are overlaid. The distance between the skin surface and HIFU focus is 13.8mm. The acoustic pressure at the skin is about one tenth of the peak pressure of HIFU beam.

The beam profile at the skin surface is shown in Fig. 4 (a: blue line). Fig. 6 shows the beam profile at the skin which is superimposed on the photo of skin burn. We can understand that the area of the skin burn is related with the profile of HIFU beam.

4. Conclusion

It is effective to consider the beam profile of HIFU for better understanding of HIFU treatment results. The evaluation with HIFU irradiation time is one of our future works.

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References