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Evaluation of HIFU treatment with 3D temperature measurement phantom
3 次元温度計測ファントムによる HIFU 治療評価

Toshihide Iwahashi[1†], Kazunori Itani[2], Keisuke Fujiwara[2], Takashi Azuma[1], Kazuhiro Matsui[1], Tang Tianhan[1], Kiyoshi Yoshinaka[3], Akira Sasaki[1], Syu Tkagi[1], Yoichiro Matsumoto[1], and Ichiro Sakuma[1] ([1]The University of Tokyo; [2]Hitachi Aloka Medical; [3]AIST)
岩橋　利英 [1†]，射谷　和徳 [2]，藤原　圭祐 [2]，東　隆 [1]，松井　和洋 [1]，唐　天汉 [1]，葭仲　潔 [3]，佐々木　明 [1]，高木　周 [1]，松本　洋一郎 [1]，佐久間　一郎 [1] ([1] 東京大学, [2] 日立アロカメディカル, [3] 産総研)

1. Background

HIFU (High Intensity Focused Ultrasound) is one of promising minimally invasive treatment method (**Fig.1**). Though energy concentration causes heat coagulation around focal area, energy dispersion does not give a damage outside focus area. There are several difficulities of HIFU treatment. When tumor is larger than a HIFU focal area, multiple exposures are needed. Therefore, monitoring technology is needed, precise target definition, detecting focal spot position, beam dosimetry. If multiple foci are exposed in a sequence from a fixed position of the HIFU transducer, heat accumulation at the skin, which was exposed in every HIFU shot, will increase the risk of skin burn. In order to prevent skin burn, it needs sufficient intervals to cool an entrance surface of HIFU beam.

In order to establish temperature contorol technique, temperature distribution caused by exposure of HIFU was visualized with phantom. In previous works, thermocouple, infrared camera, BSA (Bovine serum albumin), nonionic surface-active agents, TLC (thermochromic liquid crystal) sheet were used. However, it is difficult to carry out 3D temperature measurement by these methods. Thermocouple, infrared camera and TLC sheet can measure at only a single point or surface. BSA and nonionic surface-active agents are binary measurement.

In this study, 3D temperature measurement phantom with MTLC (micro-capsuled TLC) is used. And HIFU treatment is evaluated. Previous work developed the phantom to visualize the 3D temperature distributions caused by exposure of high frequency electromagnetic fields [3]. In this study, 3D temperature distributions caused by exposure of HIFU was visualized.

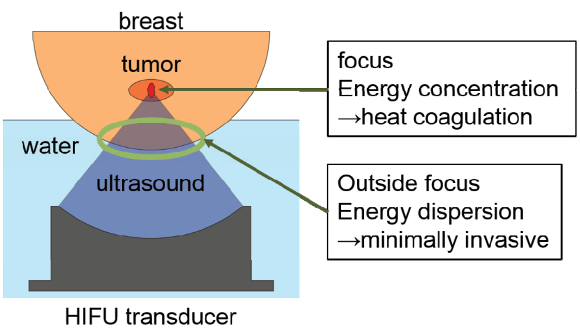

Figure 1 HIFU treatment

2. MTLC (micro-capsuled thermochromic liquid crystal) phantom

MTLC is micro capsule whose diameter is 30 micro meters and specific gravity is 1000 kg/m^3. It reflects light alternatively according to temperature. This is because MTLC has spiral structure and its pitch change according to temperature. Like Bragg reflection, the light corresponding to a pitch is reflected strongly. The wavelength of reflected light becomes shorter as temperature goes up. In other words, reflected light changes from the red to purple as temperature goes up (**Fig.2**). MTLC visualizes temperature distribution. Since this phenomenon is reversible, exposure experiment can be conducted on the same conditions repeatedly. When the transparent material with which MTLC was mixed is illuminated with a light sheet, the temperature distribution of the illuminated section can be visualized. Arbitrary sections can be visualized by changing how to apply a light sheet. 3D temperature distribution can be acquired with scanning with a light sheet.

The propagation media of ultrasound in a phantom is required for being colorless and transparent, not convecting, and having the characteristic near a living body. In addition, it needs to contain scatterers for ultrasound imaging. In this study, urethane is used as a propagation media which fulfills these conditions to some extent. In addition, it contains glass beads (average diameter 32 micro meters, specific gravity 1000 kg/m^3) as scatterers.

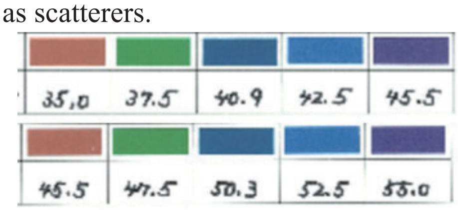

Figure 2 color and temperature of two kinds of MTLC

3. Experiment

The phantom was exposed with HIFU within a water tank in dark room (**Fig.3**). Its temperature was 23 degrees and its dissolved oxygen was 1.18 mg/L. The light sheet was reflected by the mirror on the phantom, and it illuminated the phantom. The visualized section of the phantom could be moved by moving the mirror. A light sheet with thickness of 4mm was emitted from a xenon light source with output power of 150W. The size of a phantom was one-side a 50-mm cube. It contained 0.013%wt MTLC which reflected light in 35 to 45 degrees and 0.014%wt MTLC which reflected light in 45 to 55 degrees, and 0.11%wt glass beads. Its acoustic velocity was about 1400 m/s.

The focal length and center frequency of the HIFU transducer was 100 mm and 2MHz, respectively. The phantom was exposed by 6.3W for 60 seconds. The ultrasound probe was attached in the center of the HIFU transducer. The ultrasound probe receives echo signals generated through scattering of the HIFU beam to visualize the HIFU beam shape (HBI : HIFU beam imaging).

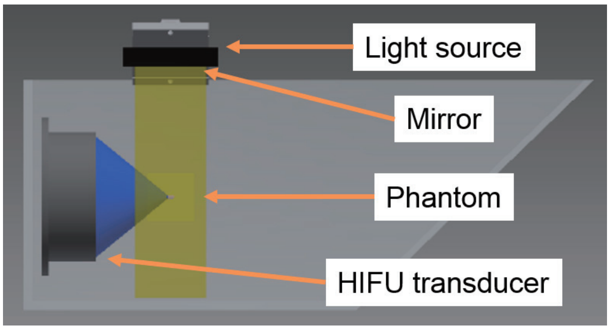

Figure 3 experiment

4. Result and Discussion

Only HIFU beam in the phantom region including scatterers was clearly visualized as shown in **Fig.4**. Its focal spot position could be estimated based on this image. Small white dots in the image were artifacts caused by electric noise through its line of power supply. In this HBI, phantom surface was also clearly imaged as a white vertical line.

Fig. 5 shows temperature distribution caused by exposure of HIFU beam. The high temperature domain spreads out from the focal area gradually in this measurement time range was clearly imaged. Figures of 15s and 30s shows only MTLC (35-45 degrees) colored. Figures of 45s and 60s shows two MTLCs colored and MTLC (45-55 degrees) colored in an elliptical form. By using this wide rage measurement both in spatial and temperature range, temperature distribution around the focus and at the object surface could be observed in simultaneously. In our research, a pivot motion exposure method to expand its area of approaching path was developed. In the current our plan, temperature suppression effect at the object surface will be quantitatively estimated. In addition, the spatiotemporal resolution and estimated temperature accuracy will be evaluated and discussed in the conference.

5. Conclusion

The gel which was optically transparent and invisible acoustically was able to be made by mixing MTLC and glass beads with urethane. Therefore, the focal area by sound and the temperature distribution by light were able to be visualized by the same phantom. The proposed method cloud visualized thermal distribution in a wide temperature range using two kinds MTLC.

Acknowledgment

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Figure 4 HBI

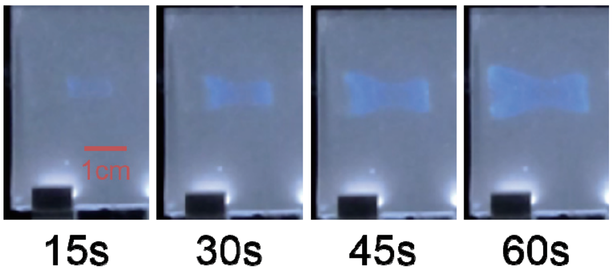

Figure 5 visualized temperature distribution