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Verification of cavitations and thermal effects of Ultrasonically activated scalpel
超音波凝固切開装置のキャビテーション作用と熱作用検証

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1. Introduction

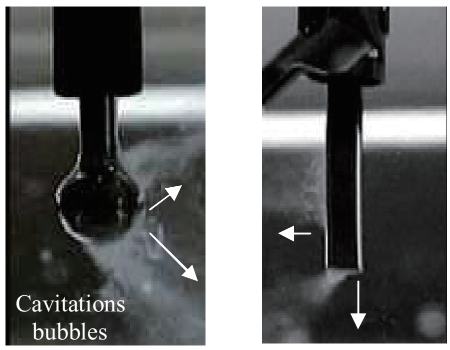
Ultrasonically activated scalpel (UAS) is a surgical device utilizing ultrasonic energy to perform incision and coagulation simultaneously. The active blade at the tip is the specification which vibrates on the frequency of 55.5 kHz. Incision is mechanically performed by repeating that the vibrating blade extends an organization locally beyond an elastic limit. Coagulation is performed when the frictional heat by vibration of a blade carries out heat denaturation of the protein in a living body tissue. In laparoscope-assisted surgery, the UAS is used widely. But there is a concern that the UAS may give undesirable damage to the surrounding tissues during surgical operation by tissue effect of sound. Although cavitations and thermal effects of the UAS are considered as mechanism of the damage to tissues, engineering verification is very insufficient.

In this paper, we presenrt the observation of generation of the cavitations bubbles in the water, the acoustic pressure emitted from the blade, observation of the cavitations effect of ultrasound to porcine mesenterium tissue, and tempreture distribution on the porcine mesenterium around the blade during activation was observed by an infrared thermography.

2. Observation of cavitations bubbles

When the cavitations bubbles collapse, they force liquid energy into very small volumes. Although the collapse of a cavity is a relatively low-energy event, highly localized collapses can erode metals over time, and damage tissues. It is important to observe where cavitations bubbles generate.We observed the generation of cavitations bubbles around the blade in degassed water. We lighted up the water from side of the water tank, and took photographs using a high speed camera (Casio EXILIM EX-F1).

Figure 1 shows cavitations bubbles near the ball type and grasp type blades. In these cases, the UAS worked with maximum output. It was observed that the amount of cavitations bubbles increases as we increased output of the equipment. In ball type blade, bubbles were generated from upper and lower part of blade as shown in **Fig.1 (a)**. The generating position changed irregularly along the circumference. Since the vibration distribution of ball blade is almost uniform, the generating position of these cavitations bubbles changes irregularly. In grasp type blade, bubble generation mainly from the blade end was observed, shown in **Fig.1 (b)**. The bubbles that generated near the blade are carried by acoustic streaming.



(a)Ball type blade (b)Grasp type blade

Fig.1 Cavitations bubbles from blades.

3. Acoustic pressure of the UAS

To estimate the cavitations effect of the tissue, we measured the acoustic pressure emitted from the blade in degassed water and canola oil which is hard to generate cavitations bubbles, using hydrophone. The hydrophone was fixed at the point of 1 mm from the blade.

Figures 2 and **3** show the received waveform and its frequency analysis result in degassed water and canola oil from the grasp type blade. In **Fig.2 (b)** and **Fig.3(b)**, 55.5 kHz component which is the driving frequency of this device and also its harmonic component were observed. In **Fig.2 (b)**, some components other than them were also observed. It will be considered that this components are generated by cavitations bubbles since this

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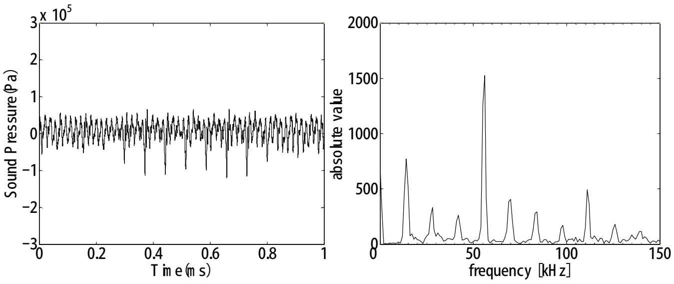
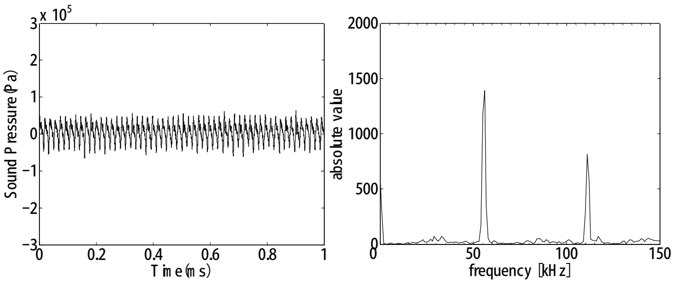
components are not observed in canola oil (**Fig.3 (b)**).



(a) Sound waveform data (b) Frequency analysis

Fig.2 Sound waveform and its spectrum in degassed water (Grasp type blade)



(a) Sound waveform data (b) Frequency analysis

Fig.3 Sound waveform and its spectrum in canola oil (Grasp type blade)

4. Verification of cavitations effect

We verified whether a cavitations effect would affect even the position distant from the ultrasonic vibration source. We changed the range where the distance between the end face of the blade and porcine mesenterium, and examined the range where tissue effects spread. We used the grasp type blaed, and it was activated for 10 seconds to porcine mesenterium. In order to produce a cavitations effect easily, the blade and the mesenterium tissue were dipped into the physiological saline. Then, histological examination of the specimen was performed.

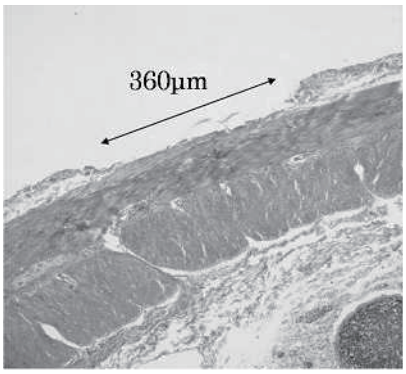


Fig.4 Specimen of the tissue (detached distance : 0.1mm)

No histological damages were observed on the specimens detached from the blade with a distance of 0.3 mm or more, whereas damages to subserosa and musclaris propria were observed, with a distance of 0.1mm and in contact with serosa, respectively.(**Fig.4**)

5. Verification of thermal effect

We observe the change of temperature distribution on the mesenterium around the blade during activation was observed by an infrared thermography.

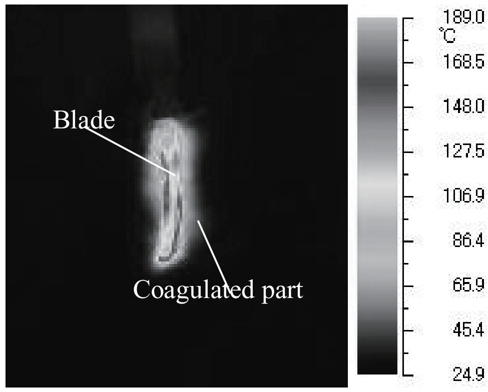


Fig.5 Thermography image (Grasp type blade)

Figure 5 shows that frictional heat in the tissue was generated by activating the blade and pad. The rise-in-temperature range of the tissue around the blade is uniform. The coagulated part was approximately in agreement with the part with high amplitude vibration. But a different temperature distribution was also observer. If the tissue with a tube structure such as a blood vessel exists, there is possibility that the tissue is damaged along the tube direction by vaporization and expansion. It is required more detailed verification of the tissue effect in special structures, such as tube structure.

4. Conclusion

In this paper, we verificated cavitations and thermal effects of ultrasonically activated scalpel. Cavitations bubbles are observed in degassed water, and they generated locally near the blade, and it is thought that the collapse of bubbles is also localized near the blade. In clinical surgery, it is considered that the influence on the living body tissue by the cavitations effect is smaller than the thermal effect.

Acknowledgment

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