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Evaluation of sound field near blade of ultrasonically activated surgical device
超音波凝固切開装置のブレード近傍の音場評価

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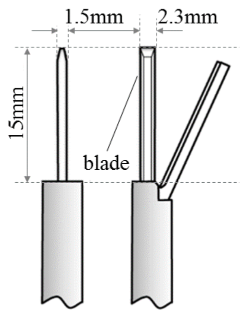
1. Background of this study

In recent years, some studies reported that unexpected postoperative pancreatic leakage occurs significanly more frequently after laparoscopic surgery as compared with conventional open surgery for gastric cancer [1]. Pancreatic leakages lead to pancreatic fistula, that could cause severe complications such as postoperative hemorrhage and intra-abdominal abcess. Therefore, detailed analysis have been eagerly awaited to reveal the mechanism to develop such pancreatic damages.

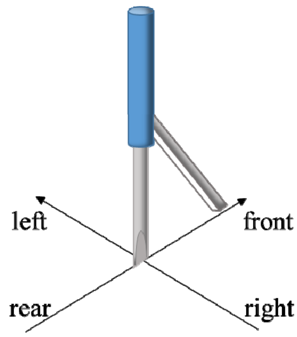
Recently, ultrasonically activated devices (USADs) have been suggested to cause the pancreatic tissue damages during surgeries [2]. USADs could develop "cavitation", which has harmful effects on biological tissues, as well as frictional heat in association with the ultrasonic vibration of the blades. In order to analyze distributions of the "cavitation" generated from USADs, sound field analyses around the activated blades were conducted with the use of pressure sensitive papers.

2. Methods and materials

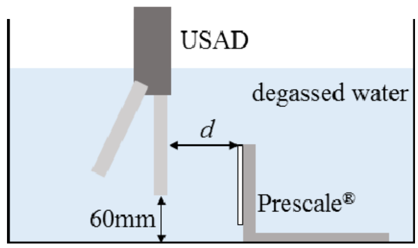
A laparoscopic USAD with a straight blade (Covidien, Sonicision^{TM}) was used in this study. The configuration of straight blade is shown in Fig. 1(a). Figure. 1(c) shows the experimental setting in this study. USAD handpiece was fixed on a precision positioning stage and its blade is immersed in a transparent acrylic water tank filled with degassed water. The size of water tank is length 20 cm, width 20 cm, and height 30 cm. Pressure-sensitive films (Prescale®, Fuji Film, Tokyo, Japan) were placed close to the blade and the USAD was continuously activated for 60s with a frequency of 55.5 kHz. The displacement amplitude of the tip of the blade was designed to be 83.8 μm. The film detects static pressure, but not dynamic pressure, with a range from 50 to 200 kPa, and turns magenta from white in color. The film was placed in the "rear" or "right" direction as indicated in Fig 1(b). The distance between the blade and the film was set within a range from 0 to 1.0 mm with an increment of 0.2 mm, acquiring data three times with each distance. After the data



(a) Configuration of straight blade



(b) Aspects of the blade analyzed



(c) Arrangement of USAD and pressure-sensitive film

Fig. 1 USAD used this study.

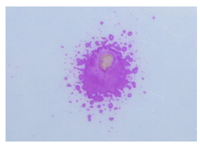


Fig. 2 The developing pressure measurement film

acquisition, colored areas on the film were quantified using image processing software (NIH ImageJ). Photographic image of the color development areas were converted into gray scale data (8bits) and binarized by discriminant analysis to extract the color development areas. Then, the effective radius (R_{eff}) was calculated with the definitions as follows;

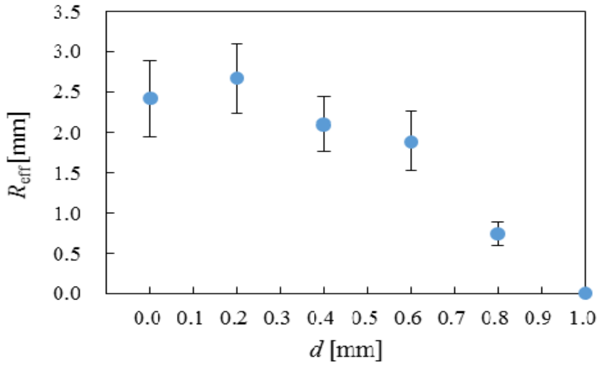
$$R_{eff} = \sqrt{\frac{S}{\pi}}. \quad (1)$$

3. Results and Discussion

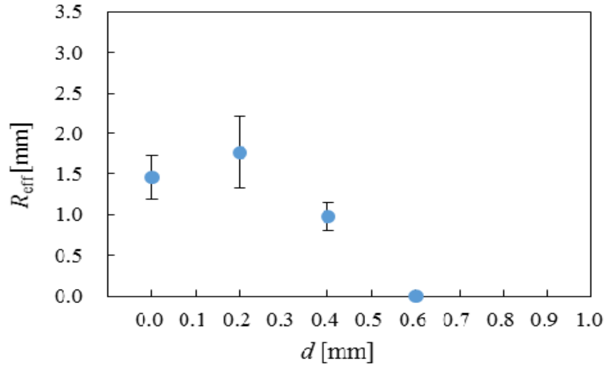
Distributions of the effective radius with each distance between the measurement film and the blade are shown in Fig. 3(a) ("right" aspect of the blade) and Fig. 3(b) ("rear" aspect of the blade). Incidentally previous study demonstrated effective radius in the vertical direction as shown in Fig. 3(c) [3]. The effective radius indicated maximum level with the distance of 0.2 mm from either aspects of the blade and decreased as the distance increased. No color development on the film was observed with the distance of 0.6 mm or more from the "rear" aspect and that of 1.0 mm from the "right" aspect of the blade. Color development areas of the "right" aspect of the blade consistently exceeded those of the "rear" aspect of the blade with the same distance.

4. Conclusion

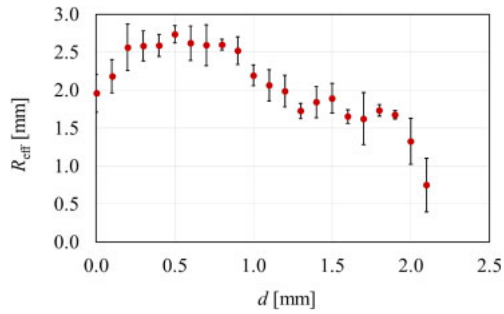
We successfully estimated the sound field around the side aspect of the activated blade of a USAD using pressure-sensitive film. The analyses indicated an asymmetric sound field, requiring further verifications such as analyses using a hydrophone. However, the results strongly suggested biologically harmful "cavitation" occurs in the vicinity of the side aspect of the activated blade.



(a) Results of the analysis on the "right" aspect of the blade



(b) Results of the analysis on the "rear" aspect of the blade



(c) Results of the analysis on the "vertical" aspect of the blade

Fig. 3 Distributions of the effective radius (R_{eff}) detected by the distance (d) from the blade

References

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