Development of Forceps-Type Microwave Coagulation Device for Surgical Operation

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***Abstract*—In recent years, various types of medical applications using heating effect of microwave have widely been investigated and reported. In this study, a novel forceps-shaped device for surgical operations such as blood vessel sealing is proposed. This device has two meander radiation elements to heat up biological tissue between them using microwave energy. In this paper, proposed device was numerically modeled and heating characteristics was evaluated by numerical calculations. As a result, heating capability of the proposed device was confirmed.**

Index Terms—surgical device; microwave; thermal effect; FDTD calculation.

I. Introduction

In recent years, various types of medical applications of microwave have widely been investigated and reported [1]. For example, microwave hyperthermia [2], and microwave coagulation therapy (MCT) [3] for treatment of cancer, cardiac catheter ablation for ventricular arrhythmia treatment [4], thermal treatment of benign prostatic hypertrophy (BPH) [5], etc. In all these techniques, the thermal effect of biological tissue by the microwave energy is used. In this study, we apply this thermal effect to development of surgical devices.

In our previous study, a microwave forceps for coagulating and cutting thin biological tissues such as blood vessel was proposed for laparoscopic surgery [6]. Fig. 1 shows structure of the previous device. This device is consisted of two parts (upper part and lower part) to grasp biological tissue. The upper part is equipped with a heating antenna and the lower part is equipped with a cutting blade. Biological tissue is grasped between the two parts and heated up by the heating antenna. Then, coagulated tissue is cut with the blade. As a result, this device has sufficient capability of coagulating grasped tissue for hemostasis. However, temperature distribution of heated tissue is not uniform because the device radiates microwave from only upper part of the device.

In this study, in order to realize uniform heating of grasped tissue, microwave forceps with heating element in both parts of the device is designed. The coagulating capability of the proposed device was evaluated by the numerical calculations of electromagnetic field and temperature distribution using finite-difference time-domain (FDTD) method. Moreover, for numerical analysis of temperature distribution in biological tissue, bioheat transfer equation is employed [7].

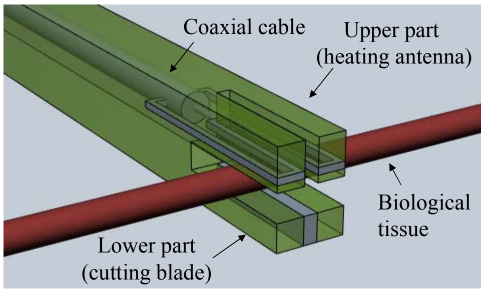


Fig. 1. Structure of the previous device.

II. Structure of Proposed Device

Fig. 2 shows the structure of proposed device. This device is consisted of a pair of meander shape radiation elements loaded to the tip of the coaxial cable and PTFE insulation around them. Two elements have reverse meander pattern to each other in order to increase current on them. The upper part is connected to inner conductor of the coaxial cable and the other is connected to outer conductor. In this study, grasping mechanism is omitted to simplify numerical modeling. Therefore, the distance between two parts depends on the thickness of the tissue. Here, proposed device is assumed to be used in water-filled laparoendoscopic surgery (WaFLES) [8]. In this operative procedure, saline solution is employed for swelling the abdomen instead of carbon dioxide gas. Therefore, heating antenna must be designed to resonate in saline solution. The operating frequency is 2.45 GHz that is one of the industrial, scientific and medical (ISM) bands in Japan.

III. Heating Characteristics

Heating characteristics of the proposed device is evaluated numerically. Fig. 3 shows FDTD calculation model. This model simulates proposed device and grasped blood vessel inside saline solution. A blood vessel with 6 mm in width and 2 mm in thickness is concerned in this study. Initial temperature of the calculation model is set to 37°C and temperature of saline solution is kept at 37°C. In this arrangement, the reflection coefficient at the feeding point of the device is about -14.7 dB at 2.45 GHz.

Figs. 4 (a) and (b) illustrate the SAR distribution and temperature distribution on *y-z* plane at 2.45 GHz. The observation plane includes the center point of the device. Fig. 4 (a) indicates high SARs distribute only between two parts of the device. Moreover, grasped tissue is widely heated over 60°C which is coagulation temperature of biological tissues. Here, in the temperature calculation, input power of the device and heating time are set to 70 W and 10 s, respectively. These results imply that proposed device has sufficient heating capability.

IV. CONCLUSION

In this study, microwave forceps with a pair of meander shaped heating elements was designed in order to realize uniform heating of grasped tissue. The coagulating capability of the proposed device was evaluated by the numerical calculations. As a result, high SARs are obtained between two elements and grasped tissue is coagulated efficiently.

As a further study, the validity of the proposed device will be evaluated experimentally. Moreover, temperature dependence of electric and thermal constants of biological tissue including coagulated and ablated tissue will be investigated for more accurate simulation.

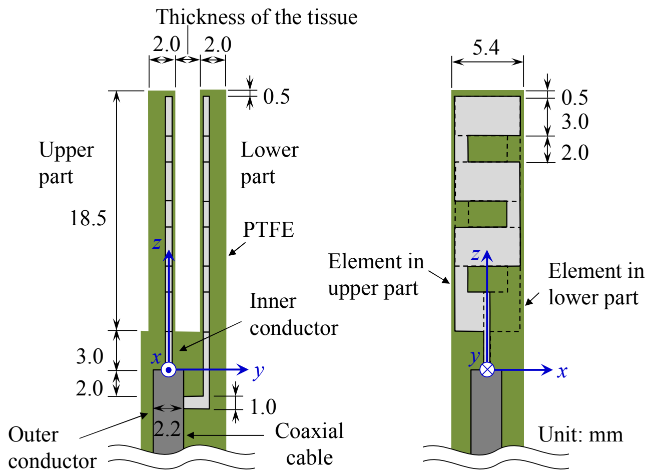


Fig. 2. Structure of the proposed device.

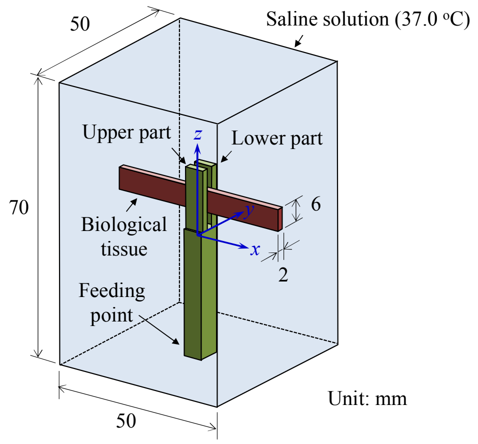
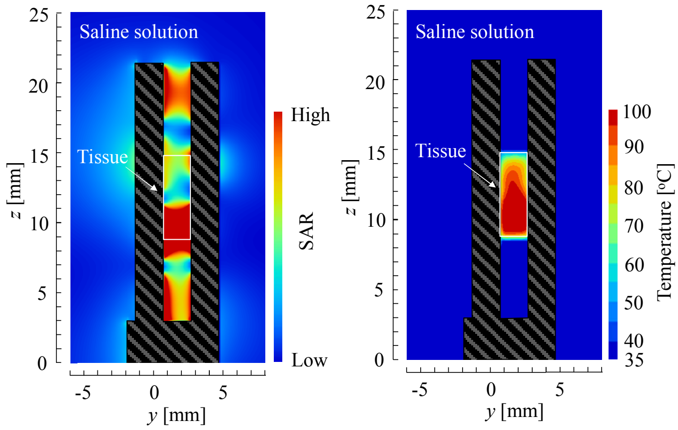


Fig. 3. FDTD calcualtion model.



(a). SAR distribution (b). Temperature distribution

Fig. 4. Calculated results.

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