Development of Hybrid Surgical Device Combining Microwave and Radio Frequency Current

Sho Suzuki
Graduate School of Engineering
Chiba University
Chiba, Japan
sho.exclab@gmail.com

Kazuyuki Saito and Koichi Ito
Center for Frontier Medical Engineering
Chiba University
Chiba, Japan
kazuyuki_saito@faculty.chiba-u.jp

***Abstract*—Various types of surgical devices using microwave energy for the treatment of bleeding from the organs and blood vessels are investigated and reported. For smooth progress of the surgery, it is desirable that devices have functions of tissue coagulation and tissue resection. Generally, microwave energy is used for tissue coagulation and unsuitable for tissue resection because of the mild heating effect. Here, devices using joule heating due to radio frequency current are employed for tissue resections. In this study, a coagulation and cutting device with the microwave energy which has a good coagulation characteristic and radio frequency current which has a good dissection characteristic is proposed. In this paper, the heating characteristic of the designed microwave heating antenna loaded with the coagulation and cutting device was evaluated using finite-difference time-domain method and bioheat transfer equation. As a result, the designed antenna heats the grasped blood vessel more than 60 ºC around the heating antenna.**

Keywords—surgical device; microwave antenna; heating characteristic; FDTD calculation;

I. INTRODUCTION

Recently, minimally invasive surgery has been widely performed to lessen physical burden of the patient. One of the minimally invasive surgery is laparoscopic surgery using the laparoscope. Figure 1 shows the outline drawing of laparoscopic surgery. In laparoscopic surgery, laparoscope and some surgical instruments are inserted into the body through approximately 10 mm diameter holes. Therefore, surgical instruments used in laparoscopic surgery are required to have multiple functions such as tissue coagulating and cutting [1], [2]. The representative energy device used in laparoscopic surgery is an electric scalpel. The electric scalpel can realize both tissue coagulation and dissection by the Joule heating due to the radio frequency (RF) current flowing between an active electrode and a return electrode. However, when an electric scalpel coagulates the biological tissue, this device has some problems such as overheat of tissue [3]. By the way, one of the tissue coagulating method other than using RF current has the method using microwave energy [4], [5]. This method, employs the dielectric heating, can heat slowly and can prevent carbonization of the biological tissue due to the over heating. Moreover, heating will stop if water in the biological tissue completely evaporate.

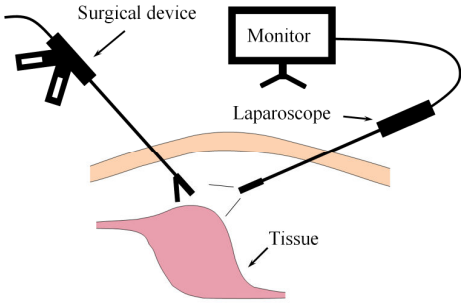


Fig. 1 Laparoscopic surgery.

In this study, we proposed a tissue coagulation and cutting device using microwave energy and RF current. This device has grasping mechanism like forceps. The biological tissue grasped by this device is coagulated by the microwave and is cut the coagulated tissue by the RF current. Furthermore, a microwave heating antenna loaded with the coagulation and cutting device is designed, and heating characteristic of the designed antenna is evaluated by numerical calculation using finite-difference time-domain (FDTD) method and bioheat transfer equation.

II. CALCULATION MODEL

A. Proposed Device

Figure 2 shows the structure of the proposed device. In Fig. 2(a), designed device is composed of two parts: a fixed part and a movable part. The fixed part has the heating antenna and a copper plate assumed as the active electrode. The movable part has the copper plate assumed as the return electrode in order to cut the tissue. Each of element is covered with polytetrafluoroethylene (PTFE) in order to prevent adhesion of the coagulated tissue. In Fig. 2(b), antenna elements are connected to an inner conductor or an outer conductor of the coaxial cable. The designed device has a height of 5.0 mm and a width of 8.1 mm and a length of the gripper part is 10 mm. This device grasps the biological tissue between two parts, and coagulates and cuts the biological tissue.

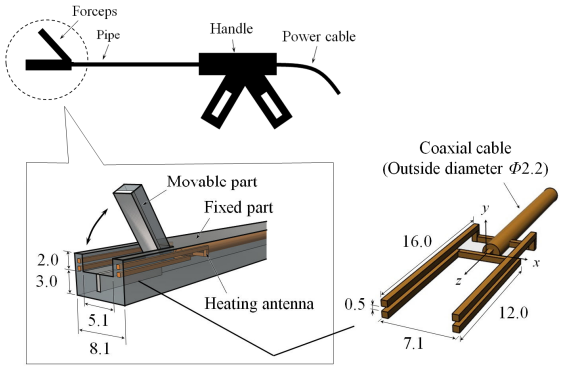
B. Calculation Model

Figure 3 shows the FDTD calculation model in the case of grasping blood vessel using the designed device. A blood ves-

sel has 1 mm in thickness and 6 mm in width. The designed device grasps it in the air. Moreover, initial temperature of blood vessel is set to 37 ºC and temperature of the air is kept at 25 ºC. Mur's 1st order absorption boundary conditions are applied as the absorption boundary condition in numerical analysis of electromagnetic field. The operating frequency, input power to the device, and heating duration were set to 2.45 GHz, 8 W, and 5 s, respectively. Table 1 shows physical properties of blood vessel. In this study, the region heated more than 60 ºC is defined as coagulated region.

III. Heating Characteristics

A temperature distribution on *x*-*y* plane at the center of grasped region is shown in Fig. 4. In Fig. 4, the parts of blood vessel near the heating antenna elements are heated more than 60 ºC. Moreover, the region near the copper plates assumed as the active electrode in heated below 70 ºC. This temperature



(a) Overall view (b) Heating antenna

Fig. 2 The proposed device model.

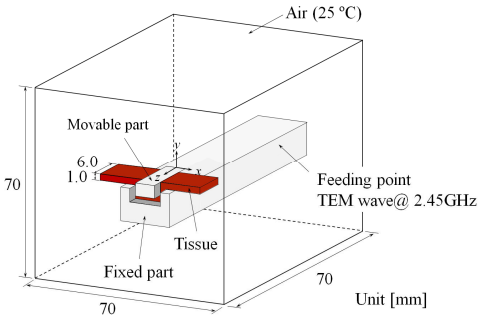


Fig. 3 The calculation model.

TABLE. 1 The electrical properties of biological tissue

Electrical Properties (@ 2.45 GHz)	
Relative permittivity	42.5
Electrical conductivity [S/m]	1.44
Thermal Properties	
Specific heat [J/kg·K]	3,306
Thermal conductivity [W/m·K]	0.46
Mass density [kg/m^3]	1,102

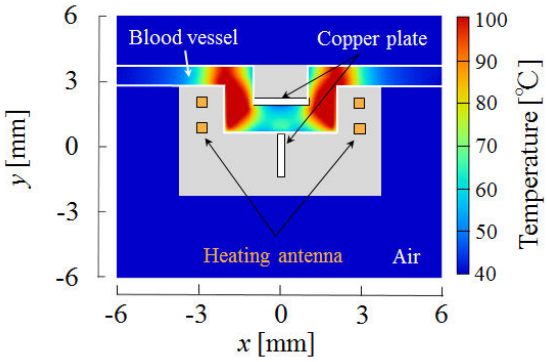


Fig. 4 The heating characteristic.

rise has little effect on cutting using RF current because the impedance of tissue increase over 90 ºC by drying of water in the tissue. For these reasons, it is confirmed that the designed antenna is useful as the heating antenna loaded with the proposed device.

IV. Conclusion

In this study, the heating antenna for the coagulation and cutting device using the microwave energy and the radio frequency current was designed. Moreover, the heating characteristic of the designed antenna was evaluated. As a result, the blood vessel grasped with the proposed device could be heated more than 60 ºC. Therefore, we confirmed that the designed heating antenna had the enough heating ability for coagulation of the biological tissue.

As a further study, the proposed device using the microwave energy and the RF current will be produced and its heating characteristic will be evaluated experimentally.

Acknowledgment

This work was supported by Grant-in-Aid for Scientific Research (C) Grant Number 15K06010.

References

[1] T. Takayama, T. Omata, R. Oshima, M. Osaki, H. miyamoto, K. Kojima, K. Takase, and N. Tanaka, "Assemblable Tools for Laparoscopic Surgery," Micro-Nanomechatronics and Human Science (MHS 2010), pp. 59-64, Nov. 2010

[2] Y. Endo, K. Saito, and K. ito, "The Development of Forceps-Type Microwave Tissue Coagulator for Sugical Operation" IEEE Trans. Microwave Theory Tech., vol.63, no.6 pp.2041-2049, June 2015.

[3] K. Gallagher, B. Dhinsa, and J. Miles, "Electrosurgery," Surgery, vol. 29, Issue 2, pp. 70-72, Feb. 2011

[4] M. Converse, E. J. Bond, S.C.Hagness, and B. D. Van Veen, "Ultrawide band microwave space-time beam-forming for hyperthermia treatment of brest cancer: a computational feasibiity study," IEEE Trans. Microwave Theory Tech., vol. 52, pp. 1876-1889, Aug. 2004.

[5] P. Liang, B. Dong, X. Yu, D. Yu, Z. Cheng, L. Su, J. Peng, Q. Nan, and H. Wang, "Computer-aided dynamic simulation of microwave induced thermal distribution in coagulation of liver cancer," IEEE Trans. Microwave Theory Tech., vol.52, pp. 1876-1889, Aug. 2004.