Thin Microwave Antenna for Intracavitary Heating of Bile Duct Carcinoma - Experimental Evaluations on Performances of Antenna using a Swine -

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Abstract

In recent years, various types of medical applications of microwaves have widely been investigated and reported. Among them, microwave thermal therapy is one of the useful applications and is modality for cancer treatment. In this treatment, there are several schemes of microwave heating. The authors have been studying thin coaxial antenna for intracavitary microwave heating aiming at the treatment of bile duct carcinoma. In this treatment, an endoscope is first inserted into the duodenum and a long and flexible coaxial antenna is then inserted into the forceps channel of the endoscope, which is used to insert the tool for surgical treatment. Finally, the antenna is guided to the bile duct through the papilla of Vater, which is located in the duodenum, and is inserted in the bile duct. Up to now, the heating characteristics of the antenna are investigated by numerical simulation, experiment using tissue-equivalent phantom and extracted organs. In this study, the authors have an experience on animal experiment using a swine. In the experiment, temperature rises around the antenna inserted into the bile duct were measured. From the results of this experiment, cooling effect by blood circulation was cleared.

1. Introduction

In recent years, various types of medical applications of microwaves have widely been investigated and reported [1]. They are microwave hyperthermia [2],[3] and microwave coagulation therapy (MCT) [4],[5] for medical treatment of cancer, cardiac catheter ablation for ventricular arrhythmia treatment [6],[7], thermal treatment for benign prostatic hypertrophy (BPH) [8],[9], etc. Until now, the authors have been studying microwave antennas for hyperthermia and coagulation therapy. The hyperthermia is one of the modalities for cancer treatment, utilizing the difference of thermal sensitivity between tumor and normal tissue. In this treatment, the tumor is heated up to the therapeutic temperature between 42 and 45 °C without overheating the surrounding normal tissues. Meanwhile in the coagulation therapy, target tumor is heated more than 60 °C to generate a coagulated region including the cancer cells. Although there is a large difference between their therapeutic temperatures, heating scheme is similar except for output microwave power from the antenna.

There are a few methods for heating the cancer cells inside the body. In this study, heating performances of intracavitary heating system for treatment of bile duct carcinoma are investigated. In many cases, the strictures of bile duct due to the growing the cancer cells can be dilated by stent placement. However, a new treatment method is needed to prevent restenosis that may occur after stenting. Figure 1 shows a scheme of the treatment; the scheme involves the use of an endoscope equipped with a microwave antenna. In this treatment, first, the endoscope equipped with a long flexible microwave antenna in its forceps channel is inserted noninvasively into the duodenum. Then, the antenna is guided into the bile duct through the papilla of Vater, which is located in the duodenum, by the forceps channel of the endoscope. Finally, the target tumor is locally heated by the radiated microwave energy.

Figure 2 shows the structure of a coaxial-slot antenna [10], which is one of the antennas for intracavitary microwave heating. The antenna consists of a flexible coaxial cable so that it can be easily operated when it is inserted into the endoscope. An antenna slot is cut out on the shield of the coaxial cable, and a short circuit occurs between the conductor and the shield of the tip of the antenna. Only the tissue near the tip of the coaxial-slot antenna will be heated. Moreover, a thermocouple is provided at the center of the slot. The heating pattern around the antenna can be controlled by varying the slot parameters such as the number, position, and width of the slots. In this study, the antenna with only one slot is used.

The authors have been studied the performances of the antenna by use of a tissue-equivalent phantom and extracted liver tissues of swine. However, the effect of blood flow cannot be determined using them. Therefore, in this study, cooling effect of the blood circulation in the living swine will be observed aiming at the hyperthermic treatment.

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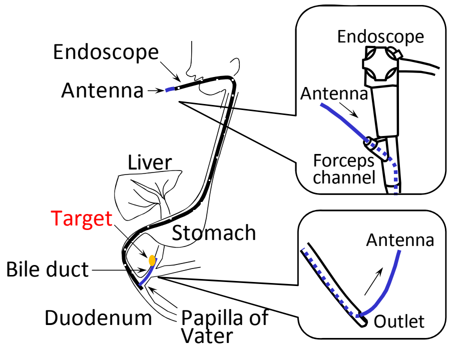


Fig. 1 Scheme of treatment for bile duct carcinoma.

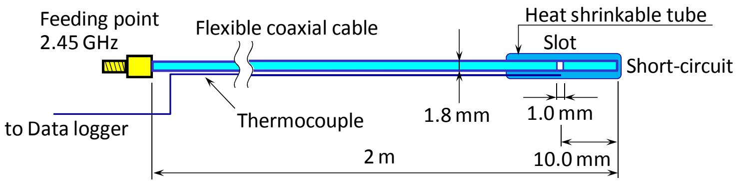


Fig. 2 Basic structure of coaxial-slot antenna.

2. Experimental Procedure

Figure 3 shows the experimental setup used in the animal experiment. The swine used in the experiment was three-months-old and weighed 49.15 kg. In actual treatment, an antenna is inserted noninvasively with the endoscope. However, in the experiment, the detection of the papilla of Vater of the swine with the endoscope was difficult. Therefore, in the experiment, the antenna was inserted invasively at laparotomy.

First, the resupine swine was given a general anesthetic. In order to prevent the loss of body heat in the experiment, electric blanket was put at the swine back. Then, an incision was made in the duodenum, and an orifice was created on the mucosal side of the digestive tract to insert the antenna into the bile duct, and the antenna was inserted into the bile duct through the papilla of Vater. Microwave frequency was given at 2.45 GHz, which is one of the industrial scientific and medical (ISM) frequencies. Moreover, the temperature of the outer surface of the bile duct was measured by using an optical fiber thermosensors and a thermocouple on the antenna. The optical fiber thermosensors were inserted into a thin and long catheter. A photograph during the experiment is shown as Fig. 4. The distances between the antenna and the thermosensors were calculated using X-ray images, which was produced at different angles such as Fig. 5.

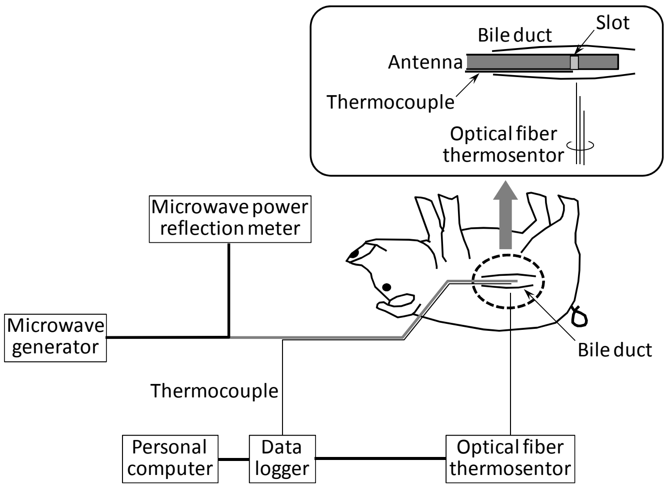


Fig. 3 Experimental setup.

Fig. 4 Photograph during experiment.

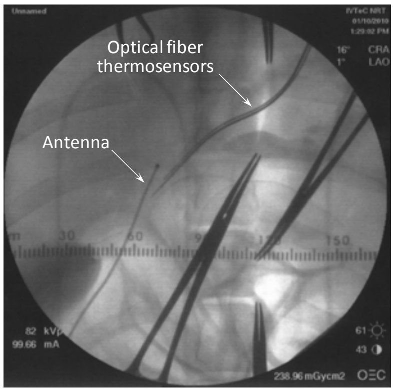
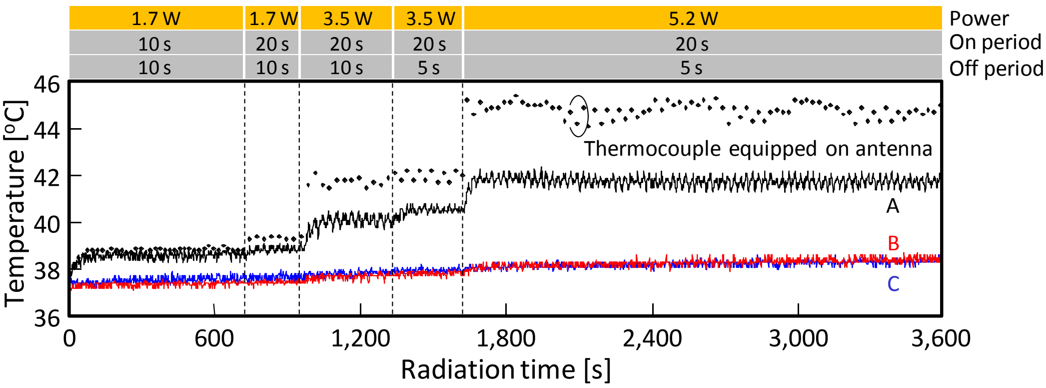


Fig. 5 Example of X-ray image.

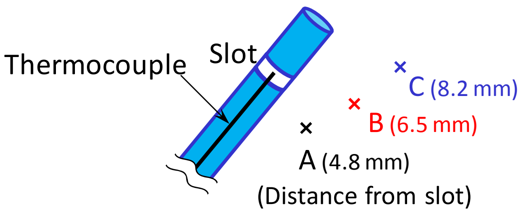
3. Measured Temperature

Figure 6 shows the result of the experiment. In Fig. 6(a), the temperatures measurement by using the optical fiber and the thermocouple are shown. Here, temperature at each time instant was measured by using the thermocouple during no microwave irradiation a period of 2 s so that electromagnetic interference could be avoided. Moreover, in this figure, feeding schemes are also indicated. In addition, Fig. 6(b) shows positions of the three optical fiber thermosensors.

It should be appreciated that the temperature rises in proportion to the input power. In this case, the maximum temperature rise is less than 10 °C. On the other hand, according to our previous study [11], which were employed extracted organs, maximum temperature rises were more than 20 °C under the almost same input power. This is due to the cooling effect of the blood perfusion. So, it may say that the blood perfusion greatly affected microwave heating for the living tissue.



(a) Temperature transition and scheme of feeding.



(b) Position of thermosensors.

Fig. 6 Temperature transition during microwave radiation and position of thermosensors.

4. Conclusion

In this paper, the experimental evaluation of microwave antenna for use in thermal treatment of bile duct carcinoma is described. The temperature could be maintained at 42 °C for 30 min without any problems by the microwave radiation at the observation point "A" in Fig. 6(b). Moreover, we confirmed that the blood flow around the bile duct significantly affected the increase in the temperature. As a further study, practical microwave antenna for actual clinical treatment will be developed in collaboration with manufactures of medical devices.

5. Acknowledgments

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