An Improved Tumour Temperature Measurement and Control Method for Superficial Tumour Ultrasound Hyperthermia Therapeutic System

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Abstract. In tumour hyperthermia therapy, the research on measurement and control of tumour temperature is very important. Based on the hardware platform of superficial tumour ultrasound hyperthermia therapeutic system, an improved tumour temperature measurement and control method is presented in this paper. The experiment process, data and results are discussed in detail. The improved method will greatly reduce the pain and dread of the patients during the therapy period on the tumour temperature measurement and control by using the pinhead sensor.

1. Introduction
Cancer is a kind of disease that seriously threatens people's health and lives. It has been a long time for human being to struggle with cancer. In recently, hyperthermia has become a kind of new cancer therapy method after operation therapy, radiopharmaceutical therapy and biology therapy \([1-3]\). Because cancer hyperthermia therapy have the high requirement of temperature measurement and control accuracy, the research on characteristic of temperature measurement and control methods is required. Based on the hardware platform of superficial tumour ultrasound hyperthermia therapeutic system, an improved temperature measurement and control method will be discussed in this paper.

2. Principles of superficial tumour ultrasound hyperthermia therapeutic system
According to the theory of hyperthermia therapy, the temperature of target tumour should be heated to 42 centigrade degree and kept it during the whole therapeutic process \([4,5]\). The tumour will be withered after a long time’s heating.

The theory of superficial tumour ultrasound hyperthermia therapeutic system is shown in Figure 1. Ultrasound is amplified by power amplifier and sends energy to the target tumour by the ultrasound hyperthermia therapeutic head. There are four pinhead sensors in the system. One pinhead sensor is to measure the cooling water temperature, and the other three pinhead sensors should be inserted into the target tumour, monitor point and superficial cuticle during the therapy process. To control the temperature of target tumour, industry computer should measure the temperature and control the power output of ultrasound by some algorithms.

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3. Description of improved method

3.1. Base of the improved method

The discussion above shows that the measurement and control of target tumour temperature are the key techniques. Because at least one pinhead sensor should be inserted into the target tumour, the temperature measurement is light scathe. Some of the other scatheless temperature measurement ways can not be used in this system for precision, size and mechanical structure problems [6,7]. The ultrasound hyperthermia therapy is a long period and the insertion of the pinhead sensor may bring the pain and dread to the patients. So, an improved temperature measurement and control method for superficial tumour ultrasound hyperthermia therapeutic system is advanced.

One ultrasound hyperthermia therapeutic period is about 4 to 6 times and one patient should have 2 to 3 times therapy per week according to the respective status. The shape and the size may not change a lot after each therapy process. It means that the distribution of tumour thermal field will not change a lot after each therapy process. We should record the ultrasound power output of the therapy process in the first time of each therapy period and use the recorded data to control the rest therapy processes in the same therapy period. It is to say that the pinhead sensor will not be inserted into the patient body and the rest therapy processes in the same therapy period are scatheless. The improved method will greatly reduce the pain and dread of the patients. The following part will verify the correctness and validity of the improved method.

3.2. Testify of the improved method

The tissue-equivalent material experiments are designed to verify the correctness and validity of the improved method. First of all, choose one tissue-equivalent material with 8cm length, 8cm width and 8cm height. Insert the pinhead sensor into the middle of the tissue-equivalent material. To simulate the tumour therapy process, the pinhead sensor should be in the same position in each experiment. Set the target temperature to the 35.0°C, 38.0°C, 40.0°C, 42.0°C separately and adjust the original temperature of the tissue-equivalent material. After setting the target and original temperature, add the ultrasound on the tissue-equivalent material and record the 60 minutes control voltage data that control the power of ultrasound output in a database. Adjust the original temperature and use the recorded database to control the ultrasound outputs of the following experiments. A lot of experiments have been done to verify the correctness and validity of the improved method. To specify the result, 2 temperature curves as shown in figure 2 are chosen.

Figure 1. Theory of superficial tumour ultrasound hyperthermia therapeutic system.
(a) therapeutic time: 60 minutes, Target temperature: 35.0°C, room temperature: 20°C, original tissue-equivalent material temperature: 24.3°C, set the tissue-equivalent material temperature higher than original temperature(25.8°C), set the tissue-equivalent material temperature lower than original temperature(22.8°C)

(b) therapeutic time: 60 minutes, Target temperature: 42.0°C, room temperature: 20°C, original tissue-equivalent material temperature: 24.3°C, set the tissue-equivalent material temperature higher than original temperature(25.8°C), set the tissue-equivalent material temperature lower than original temperature(22.8°C)

Figure 2. Temperature curve of tissue-equivalent material experiments.
Therapeutic period in temperature curve (a) and (b) of figure 2 is 60 minutes. There are 3 temperature curves in each figure. In figure 2(a), the original tissue-equivalent material temperature is 24.3°C. In the following experiments, when the tissue-equivalent material temperature is same to the original temperature of the first experiment, the temperature curve of monitor point is almost superposed with the original temperature curve under the control of the voltage data recorded in the database. When the tissue-equivalent material temperature is 25.8°C, which is higher than original temperature of 24.3°C, the temperature of monitor point will exceed the target temperature during the therapy process. But, with the progress proceeding, the temperature of monitor point will tend to the target temperature and superposed with the original temperature curve finally. Furthermore, If the tissue-equivalent material temperature is not much higher than the original temperature, which is generally in 2°C range, the exceed temperature will also be in the therapy range. When the tissue-equivalent material temperature is 22.8°C, which is lower than original temperature of 24.3°C, the temperature risen speed of monitor point will be slower than the original temperature curve. But, with the progress proceeding, the temperature of monitor point will tend to the target temperature and superposed with the original temperature curve finally. Adjust the parameters of the original temperature and the target temperature and do the same experiments as is described above, temperature curves of figure 2(b) is got which have the same trend with the figure 2(a). The results of above experiments show that, if the initial temperature of the following therapy process is quite near to the original temperature of the first therapy process, the temperature curve is quite similar to the first therapy process.

The following animal experiment is designed to verify the correctness and validity of the improved method.

[Image of Temperature Curve]

- original temperature curve
- temperature curve when initial temperature is same to the original temperature

therapeutic time: 60 min, Target temperature: 42.0°C, room temperature: 20°C,
original target tumour temperature of the first therapeutic process with inserting the pinhead sensor: 36.8°C,
original target tumour temperature of the second therapeutic process without inserting the pinhead sensor: 36.8°C

**Figure 3.** Temperature curve of animal experiment.

The rabbit with tumour in the back leg is chosen for the animal experiment. Insert the pinhead sensor into the middle of the target tumour and set the target temperature to 42.0°C. The original target tumour temperature is 36.8°C. After setting the target temperature, add the ultrasound on the tissue-equivalent material and record the 60 minutes control voltage data that control the power of ultrasound output in a database. The temperature curve is shown in figure 3.
Two days later, we use the same part and the same rabbit to do the following experiments. The original target tumour temperature is also 36.8°C in the following animal experiments. As the temperature curve shows in figure 3, under the control of the voltage data recorded in the database, the temperature curve of monitor point in the target tumour is almost superposed with the original temperature curve of the first experiment with pinhead sensor inserting into the target tumour. The following 5 therapy processes

The results of above tissue-equivalent material experiments and animal experiments show the correctness of the improved method.

4. Conclusion
The discussion above shows that the pinhead sensor should only be used in the first time of each therapy period, which includes 4 to 6 therapy processes, and should not be used in the rest therapy process of the same therapy period. The improved temperature measurement and control method for superficial tumour ultrasound hyperthermia therapeutic system, which is testified to be a correct and valid method by the tissue-equivalent material and animal experiments, can efficiently reduce the pain and dread of the patients during the light scathe therapy process. The usage of the improved method is of great important value.

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