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Microwave Renal Denervation Temperature Rise Estimation Using Machine Learning

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Energy-based medical devices have been developed and used widely in the medical field, leading to safer and faster surgery, thus improving patient quality of life. Transcatheter renal denervation (RDN) is a minimally invasive treatment that reduces resistant high blood pressure using an energy device. The device is inserted into the renal artery and heats the nerves outside the blood vessel to above 60 °C, ablating them, thus reducing blood pressure. However, confirming the temperature rise and nerves ablation has proved difficult because it is challenging to accurately know the nerves temperature outside the blood vessel. Furthermore, the patient's burden increases if we insert a thermometer probe to the ablation site inside the body. Although measuring the temperature using MRI is possible, deep site measurement accuracy is still below par.

This research proposes a temperature rise estimation at the ablation site, outside the blood vessel, using measurable temperature inside the blood vessel combined with a machine learning (ML) algorithm. Machine learning defines the inside temperature measurement's relationship with the numerical calculation data to predict the ablation temperature outside the blood vessel. Figure 1 shows the model used to acquire the dataset for ML training. It is a simplified blood vessel model using a 2.45 GHz muscle, with a cylindrical blood model running through the middle. The antenna used is a single slot coaxial antenna to deliver 2.45 GHz energy. The antenna is stabilized inside the blood model using a water balloon. A fiber-optic thermometer probe is placed on the balloon surface to measure the temperature inside the blood vessel (point A).

The numerical calculation model provides temperature data for point A (balloon surface) and B (outside the blood vessel wall), calculated using a self-developed program based on the finite-difference time-domain (FDTD) method and the bioheat transfer equation [1]. The input power of the device is set at 35 W, and the initial temperature is 37 °C, d corresponds to vessel diameter from 4 to 8 mm, with various antenna positions. The proposed ML algorithm defined the temperature relationship between points A and B. We use scikit-learn for the ML platform [2]. The ML algorithm then uses the defined relationship and point A measurement data as an input to predict the temperature increase of point B. This technique enables real-time measurement and temperature estimation at point B without using a thermometer probe outside the blood vessel. Machine learning prediction at point B shows satisfying results, with the difference between the actual value (numerical calculation results) and ML predicted values being within 1.5 °C difference.

For future works, we intend to test the ML algorithm's performance in an actual situation using a phantom to evaluate the performance of the proposed algorithm.

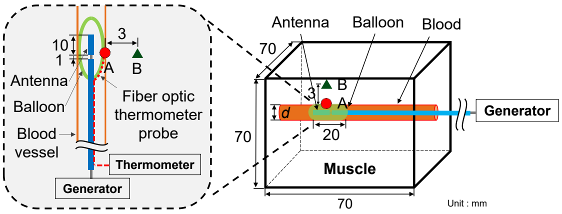

Figure 1. Proposed numerical calculation model.

1. H. H. Pennes, "Analysis of tissue and arterial blood temperatures in the resting human forearm," *J. Appl. Phys.*, vol. 1, pp. 93-122, 1948.

2. Scikit-learn homepage (https://scikit-learn.org/stable/).