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Improvement of zero-heat-flux type deep body thermometer intended for use in hot environments

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***Abstract*— We have been developing a wearable deep body thermometer based on the zero-heat-flux method [1]. In this method, to obtain the zero-heat-flux conditions, an electrical heating element has been usually used. However, considering the use in hot environments such as outdoor jobs in the summertime, air temperature usually rises higher than deep body temperature. To solve this problem, we tried to utilize a Peltier module not only for a "heating" element, but also for a "cooling" element. After simulation and building up our prototype thermometer, simultaneous measurements using a commercial device revealed that the prototype thermometer has the same accuracy as the commercial device and could maintain accurate measurement even in the high-temperature environment.**

***Clinical Relevance*— This thermometer is expected to manage core temperature even when the environment temperature is higher than core temperature.**

I. Introduction

In the summer of 2020, over 64,000 people in Japan were sent to hospital by ambulance due to heatstroke. Measuring abnormal core temperature became vital since the unusually increased core temperature is one of the early signs of heatstroke. As a continuous measurement method, the Zero-Heat-Flux method [2] could measure core temperature noninvasively from the skin surface. However, this method cannot achieve accurate measurement when the environment temperature is higher than the core temperature. This research aims to develop a noninvasive core temperature thermometer based on the Peltier module, which can keep monitoring in hot environments.

II. Methods

To maintain the measurement accuracy in hot conditions, we propose to utilize a Peltier module and a radiator. Peltier module could help pump the heat from the inside of the probe to the outside by consuming electrical energy.

A three-dimension model of probe and skin tissue was built by using COMSOL Multiphysics. The relationship between environment temperature and the measurement results was simulated and analyzed by the finite element method. Based on the simulation results, we built up our prototype thermometer. The probe consists of thermistors, insulators, an aluminum shell, a Peltier module, and an aluminum radiator. Simultaneous *in vitro* measurement experiments were carried out to compare the measurement accuracy of the prototype thermometer. A stainless vat with a rubber sheet as a heat transfer layer was immersed in a thermo-controlled water bath. The water temperature was monitored by the prototype thermometer and a commercial core temperature thermometer (CTM-205, Terumo) through the rubber sheet at different air temperatures (26°C for 30 min, 45°C for 30 min, 26°C for 30 min).

III. Results & Discussion

The simulation results show that the Peltier module and the radiator are effective in controlling the temperature of the inside part of the probe and maintaining the thermal-equilibrium state, *i.e.,* the zero-heat-flux condition of the probe. As shown in Figure 1, the measured temperature of commercial equipment rose to nearly 40°C at the same time as the air temperature rose, and gradually decreased after the air temperature returned to 26°C. As for the prototype device, the measured temperature was persistently consistent with the water temperature no matter how the environment temperature changed. The thermometer could also follow the changes of the water temperature.

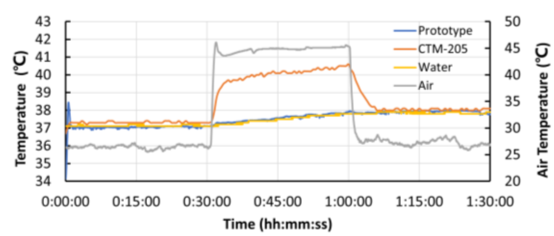

Figure 1. Simultaneous measurement temperature result

IV. Conclusion

With high accuracy and adaptability to a high-temperature environment, this thermometer is expected to serve in the core temperature management in hot conditions.

References

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