Accurate Non-Invasive Temperature Monitoring Device

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1 Background

Core temperature is one of the most tightly auto-regulated physiological processes. Anesthetic drugs compromise the body’s ability to thermoregulate. When core temperature is outside of the normothermia range, patients are at increased risk of myriad complications. Hypothermic patients are at higher risk of, among other things, increased wound infections², increased blood loss², increased ICU times and hospital stays², higher mortality rates³, increased transfusion requirements⁴. “Even mildly hypothermic patients could suffer an increase in adverse outcomes that can add costs of as much as $2,500-$7,000 per patient.”⁵ These risks are great such that clinicians actively warm hypothermic patients to achieve normothermia.

Given the importance of the core temperature on outcomes, there is a clear necessity for accurate core temperature measurement. Core temperature measurement is often misunderstood. Perhaps due to the pervasive home use of oral mercury thermometers to “take your temperature,” many wrongly assume that non-invasive core temperature is measured easily and accurately. Oral, axilla, nasal are all unreliable. Temporal/forehead and ear are particularly inaccurate. “Global authorities in anesthesiology and medicine have cited inadequacies with virtually all thermometry”⁶. False assurance or false alarm are both dangerous. There is currently no non-invasive way to reliably and accurately measure core temperature. Why is this?

The peripheral compartment is not in equilibrium with core. Fat and other layers further complicate the matter. Fat and other layers further complicate the matter. Core temperature is displayed as the core temperature. As the rate of change approaches core, the rate of flow slows. A Programmable Logic Controller (PLC) algorithm looks for the rate of change of measured surface temperature. As the rate of change approaches an acceptably low threshold, the measured surface temperature is displayed as the core temperature.

2 Methods

2.1 Disruptive Theory. Up to this point, all non-invasive core temperature measurement has measured the heat coming out of the core, which seems rational, but is unfortunately not capable of producing accurate results. Heat travels from hot to cold (2nd Law of Thermodynamics), and thus the warm core dissipates heat through the cool peripheral compartment. By the time a non-invasive measuring technique generates a reading, the actual measured temperature is some combination of warm core and cool periphery, and thus inaccurate. Furthermore, any number of variables, including peripheral body composition (fat or skinny), vasoconstriction or vasodilation, or hot or cold room temperature all negate the use of a simple offset of measured peripheral temperature.

The disruptive theory proposed by Scott Augustine, MD, is not to measure heat coming out of core muddled through a peripheral compartment, but rather to actively heat the peripheral compartment to equilibrium with core, insulate this compartment from the environment, and thus create one maximally entropic system. A body surface measurement within this insulated system must yield an accurate core temperature.

3 Results

3.1 Theory In Practice. Patients have a typical range of temperatures with normothermia in the 36-37.5°C range, and typical operating room hypothermia of 34-35.9°C. Hyperthermia or actively cooled extremes of hypothermia (e.g. in cardiac) represent further bounds of perhaps 32-40°C. In order to find core, the peripheral compartment is overheated past core, after which heating ceases. The excess peripheral heat flows into core at first quickly, then as it approaches core, the rate of flow slows. A Programmable Logic Controller (PLC) algorithm looks for the rate of change of measured surface temperature. As the rate of change approaches an acceptably low threshold, the measured surface temperature is displayed as the core temperature.

Dr Augustine proposes the ideal site of measurement to be where the base of the skull and back of the neck meet, around 1 inch from either side of the center line of the spine. This site is where arterial blood is near the surface (See Fig 1), as the vertebral artery turns and loops here.

In lab study, foam passive insulation showed a measured surface core temperature that then drops through the known core temperature. In order to mitigate this, active insulation is proposed, whereby on the other side of foam, a second “guard” heater controls to the measured surface temperature, thus eliminating radiant and conductive heat transfer out of the heated peripheral compartment. In lab, this seems to dial in on core and hold ad infinitum. An accurate non-invasive core temperature monitor would represent a significant boon for clinical decision making. A prototype of this non-invasive temperature monitor, TruCore⁷⁸ (See Fig 2) has been verified in non-hypothermic volunteers showing accuracy within 0.1°C
using rectal thermometry. A larger study with surgical patients is currently being organized.

Fig. 1 Vertebral artery (in red)

Step 5

Affix sticky probe to neck, below base of skull, off-center: goal is vertebral artery. Patient must lay probe DIRECTLY on heater.

Fig. 2 Prototype Instruction, illustrating placement relative vertebral artery and TruCore™ heater pad

4 Interpretation

4.1 Note on optimization. The time to first temperature reading is currently 3-4 minutes, whereafter equilibrium is achieved and core can be displayed in real time. It is a goal to reduce the initial reading time to sub-2 minutes. This presents challenges in that peripheral/core compartment must be maximally entropic to achieve accuracy, and rate of heating is limited to safe ranges. Time is necessary for both of these factors to play out. Optimizing seems to be as follows: the closer to actual core the peripheral compartment is heated, the less time overheating, and the less time coming back to core. Secondly, after dozens of examples, we may find patterns that allow for a predictive first number. For example, a rate of change may exist that is offset, say, 3C and 1 minute from the real number, and we may choose to display this predictive number in, say, minute 2, and tune in to the measured number into minute 3. Alternatively, we can reduce time with a best guess option which would aim the first overheat to a range of choices. For a normothermic patient the operator would press “normothermic” and the first overheat would shoot for 37.5. For a known hypo- or hyperthermic patient, the PLC aims for say 36 or 40. This would reduce time to first measurement. If no guess is made, the system aims for say 38 and operates normally, taking more time, but reducing the guess-work.

References

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