Review Article

Temperature Monitoring in the Intensive Care Unit

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Abstract

Close monitoring and management of temperature abnormalities are crucial in the critically ill to minimize the physiological and biochemical ill effects of extremes of temperature. In the intensive care unit, core temperature monitoring using either urinary, nasopharyngeal, or esophageal temperatures is recommended. One needs to be aware of the pitfalls and fallacies of other commonly used sites.

Keywords: Core, methods, nasopharyngeal, esophageal, sites, temperature

Temperature Monitoring in Critically Ill

Temperature is routinely monitored in all hospitalized patients. In the critically ill, temperature abnormalities[1] and dysregulation have been reported to be frequent,[2] and extremes of temperature have been shown to be associated with poor outcomes.[1] This article reviews the importance of temperature monitoring and describes the methods employed for accurate temperature monitoring in patients in the intensive care unit (ICU).

Is temperature regulation important?

Normally, the temperature is maintained within a narrow range by the thermostat in the hypothalamus. Body temperatures outside this range may result in deleterious effects on biochemical and cellular function. The reported biochemical abnormalities, which include hypokalemia and hypomagnesemia, can impact QT intervals.[3] Severe hyperthermia (>42°C) has effects on oxidative phosphorylation and increases the formation of heat shock proteins. This can subsequently result in a systemic inflammatory response that can progress to multi-organ dysfunction.[4] In the critically ill, where there may be additional metabolic and systemic insults, it would be intuitive to assume that it is important to measure and control temperature accurately to avoid adding insult to injury.

Do temperature abnormalities have an adverse effect on outcomes?

Fever at admission in ICU has been reported in over two-thirds of patients admitted to the ICU, whereas varying grades of hypothermia were reported in close to 20% of patients.[1] The reported effects of fever on outcome are varied ranging from adverse to beneficial. While a meta-analysis by Egi and Morita[5] has suggested that fever may not increase mortality, Circiumaru *et al*.[2] and Peres Bota *et al*.[6] reported the reverse. It is hence not clear whether this relationship between fever and mortality reflects an epiphenomenon or a true association. Treatment of fever in the critically ill with antipyretics, however, has not been shown to affect ICU free days.[7,8]

Recent research has also looked at hypothermia, not only as a negative consequence of disease but also as a treatment modality. In Laupland's study of over 10000 ICU patients,[1] there appeared to be a relationship of hypothermia with outcomes with a mortality of 22%, 38%, and 60%, respectively, in patients manifesting mild (35°C–35.9°C), moderate (32°C–34.9°C), or severe (<32°C) hypothermia. On the other hand, as a treatment modality, therapeutic hypothermia has been reported to have neurobeneficial effect in terms of reducing ischemic reperfusion injury and decreasing excitotoxicity and free-radical production.[9] While earlier studies have shown evidence of improved neurological outcomes with therapeutic hypothermia postcardiac arrest,[10,11] the most recent evidence[12] found no difference between core temperature targets of 33° versus 36°C. In other scenarios as well, there is insufficient evidence

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to suggest whether aggressive temperature control will improve outcomes.[7]

The case for accurate temperature monitoring

The high frequency of temperature abnormalities in the critically ill and the reported negative outcome association with extremes of temperature suggest that accurate monitoring of temperature and maintenance of optimal body temperature in the ICU setting is necessary to minimize the physiological and biochemical ill effects of extremes of temperature.

Which temperature should be monitored?

Temperature measurement can either be done as "core" temperature recordings or "peripheral" temperature measurements. Core temperature relates to the "compartment that is composed of highly perfused tissues whose temperature is uniform"[13] and is least affected by environmental influences as opposed to peripheral temperature sites such as the forehead, temporal, or oral, which can be easily affected by the external environment. It has been reported that there is an increase of 1°C for every 4 mm distance from the skin.[14] Given that the site of temperature regulation is the brain, it is assumed that the temperature in normal brain tissue is the gold standard for core temperature monitoring. While it would be ideal to assess core temperature, it may not always be possible, and it is hence important to understand the limitations of the device and the site monitored for clinical decision-making.

When comparing monitored temperature from different sites with the gold standard, most studies have used the definition of a clinically acceptable reflection of the core temperature if it lies within ± 0.3°C.[15,16] The different methods of temperature monitoring along with their pitfalls and advantages are described in the following section.

Brain

Clinical considerations and evidence

The temperature probe should be placed in noninjured tissue. In the absence of intracranial pathology, temperature measured from less invasive sites has reasonably correlated with the temperature in the brain. However, in the presence of brain injury, either traumatic or secondary to stroke, core temperature measurement from other sites have not accurately reflected the temperature in the brain with reported higher brain temperatures in the range of 0.4°C–2.5°C.[17] Given the invasive nature of brain temperature monitoring, there has been research looking at the accuracy of noninvasive brain temperature monitoring by magnetic resonance spectroscopy[18] as of now, this has not yet been validated for regular use.

However, the more important question that needs to be answered is whether the management of "increased" brain temperatures in the setting of intracranial pathology improves neurological outcomes.

As stated earlier, brain temperature has been shown to be higher than other core sites in the setting of brain injury. A recent randomized controlled Eurotherm trial,[7] which looked at the effects of therapeutic hypothermia after traumatic brain injury, found harm in the treatment arm with the study being terminated early due to the adverse effect of therapeutic hypothermia.

Potential pitfalls

This measurement is highly invasive and needs technical expertise to ensure that the temperature probe is placed in noninjured brain tissue.

Pulmonary artery catheter

Clinical considerations and evidence

Temperature monitoring from the pulmonary artery (PA) is also considered as the gold standard for continuous core temperature monitoring since this has been shown to be "closest to the temperature in the high internal jugular vein,"[15,16,19] which is the venous drainage of the brain.

Potential pitfalls

While this site has been considered to be the gold standard, this is also invasive and has its share of complications related to catheter insertion and maintenance. In a study on 70 ICU patients, between 20% and 30% had significant adverse events related to the PA catheter.[20] In addition, PA catheter use in the critically ill has not been shown to improve outcomes, and hence, it is not recommended in the intensive care[21] for the routine management of patients or for temperature monitoring.

Urinary catheter

Clinical considerations and evidence

Since hourly urine output monitoring is generally done for all critically ill patients, temperature sensing urinary catheters are increasingly gaining favor in intensive care. A reliable concordance of 0.92 with the PA catheter temperatures,[22] and no added procedural discomfort to the ICU patient are bonuses of this mode of temperature measurement.

In studies that compared bladder and rectal temperatures with PA temperatures, bladder temperatures performed better than rectal temperatures with a higher correlation of 0.78–0.94 as opposed to rectal temperatures where the correlation was 0.49–0.82.[23] Even though urinary thermistors have a lag in sensing rapid changes in core temperature (e.g., cooling during surgery) when compared with esophageal temperature probes, they have been reported to be faster than rectal and skin thermometers at picking up temperature variations.[24]

Potential pitfalls

Although this is not as invasive as the PA catheter, cost and infection are problems that can be associated with this device. In addition, urinary volumes can affect reliability. Better correlation with PA catheter temperatures has been observed in the presence of high urinary volumes ($r = 0.90$) as compared to low urinary volumes ($r = 0.76$).[25]

Esophageal

Clinical considerations and evidence

The esophageal probe has to be inserted in the distal third of the esophagus, and its position needs to be confirmed by a

chest X-ray.[26] In a study comparing temperatures monitored from the urinary bladder, esophageal, rectal, axillary, and inguinal with the PA temperature, the urinary temperatures, and esophageal temperatures were more reliable[27] than the other sites.

Potential pitfalls

Fluids passing through the nasogastric tubes or nasal breathing may alter the temperature.

Nasopharyngeal

Clinical considerations and evidence

The thermocouple needs to be positioned a few centimeter past the nares, and ideally, airflow should be obstructed to prevent air currents from cooling the temperature probe. This also has been shown to have reasonable accuracy with PA temperatures in children[28] and can be used to monitor core temperature.

Potential pitfalls

Airflow can alter the monitored temperature; this hence cannot be used in self-ventilating patients.

Tympanic

Clinical considerations and evidence

Since the tympanic membrane and the hypothalamus share a common blood supply from the internal and external carotids,[29,30] temperature monitoring from this site has been studied to assess correlation with core temperature.

The thermometer has to be inserted into the external auditory canal after it has been straightened by pulling the pinna in an upward and backward direction. This technique can, however, be compromised in the setting of a tortuous aural canal and obstruction by cerumen.

Potential pitfalls

Pain and tympanic membrane perforation are potential complications of this technique. Furthermore, given the technical issues and the moderate correlation with the core temperature (0.77),[22] tympanic thermometry is not considered to be reliable in critically ill patients.[22,31]

Rectal

Clinical considerations and evidence

Traditionally, the rectal route has been used to measure a patient's core temperature. However, it has been found that there is a significant lag of rectal temperature behind other core sites, particularly during rapid temperature changes.[15,32]

If used, the tip of the temperature probe should be 4 cm in the rectum as the temperature increases by 0.8º for every 2.5 cm.[14,33,34]

Potential pitfalls

Rectal perforation and discomfort for the patient are potential risks with this method. Hard feces can impair placement and inflammation and heat-producing microorganisms can affect temperature readings. In addition, rectal temperature has been shown to trail behind core temperature during rapid cooling or warming.[35]

Axillary

Clinical considerations and evidence

While this site of temperature measurement is commonly used, concordance with core temperature is only moderate with variability of 0.27°C ± 0.45°C.[27,36,37]

The thermometer must be kept in the axilla for the appropriate duration. There are different types of axillary digital thermometers available for use. One thermometer gives a quick calculated temperature value (within 30 s to 1 min); this could be one of the factors that adds to poor reliability. There are other electronic thermometers that need to be kept in the axilla for 5 min; this may be more reflective of the core temperature. By tradition, to derive core temperatures from oral and axillary temperature readings 0.3 and 0.5°C is added to the measured value, respectively. This, however, has no scientific basis and is not evidence-based! In fact no factor exists at this point of time that allows accurate estimation of temperature at one site from monitored temperature at another site.

Potential pitfalls

This does not allow continuous temperature recording, and furthermore, ambient temperature, local blood flow, and sweat can affect accuracy of the monitored temperature. It is hence not recommended for temperature monitoring in the critically ill.

Table 1 summarizes the various methods of temperature assessment, clinical considerations, potential pitfalls, and the evidence for the use of different methods of temperature recording.

How often should temperature be monitored?

It is recommended that critically ill unstable patients have continuous invasive temperature monitoring using either urinary catheter or esophageal temperature probes.[38] Specific situations in ICU where continuous temperature recording is advised are during targeted temperature management postcardiac arrest or during cooling or rewarming for extremes of temperature. This can help pick up "after-drop,"[39] which is a drop in the core temperature during rewarming of a hypothermic patient (accidental or therapeutically induced hypothermia) when cold blood is shunted to the core.

In the other hospital wards and the stable critically ill patient, it is reasonable to measure axillary temperature with the appropriate thermometer every 4–6 h.[38]

Which temperature-measuring device should be used?

The temperature measuring devices can be either nonelectrical devices, electrical devices, infrared devices or single of multi-use chemical thermometers.[13]

1. Nonelectrical devices – These contain either mercury or alcohol. Mercury thermometers are now not used given the time needed for calibration and the problems with mercury spill. Alcohol thermometers are only suitable for lower temperatures since alcohol boils at 78.5°C

Table 1: Sites of temperature recording with pitfalls and evidence

Site	Clinical consideration	Potential pitfalls	Evidence
Brain	Temperature probe should be placed in noninjured brain tissue	Highly invasive and needs technical expertise. Readings may be influenced by injury	Gold standard. In the absence of intracranial pathology, temperature measured from less invasive sites have been shown to correlate reasonably with the brain temperature
Pulmonary artery	Allows for continuous temperature recording Aseptic insertion Needs to be removed when no longer needed	Invasive and needs technical expertise Infections related to use and complications related to insertion have been reported	Gold standard. The routine use of PA catheters, however, has not been shown to improve outcomes, and additionally, there is a 30% risk of adverse events with insertion and maintenance of the catheter[21]
Urinary	Increasingly being used in critical care Requires aseptic insertion techniques and must be removed when not indicated	Cost and infection. Urinary volumes can affect reliability	Reliable correlation with PA catheter temperature in the presence of high urinary volumes[22] performs better and faster than rectal and skin temperature measurements
Esophageal	Probe needs to be in the distal 1/3 of the esophagus Position needs to be confirmed by chest X-ray	Fluids passing through NG tubes may alter the temperature	Esophageal temperatures perform reliably with PA catheter temperature recordings[27]
Nasopharyngeal	Thermocouple needs to be placed few centimeters past the nares. There should be obstruction of airflow to avoid cooling of the temperature probe	Useful only in intubated patients. Airflow can interfere with accurate temperature monitoring	Reasonable accuracy with PA catheter temperature[28]
Tympanic	The thermometer is inserted into the external auditory canal after it has been straightened by pulling the pinna in an upward and backward direction	Correct monitoring may be difficult secondary to tortuous aural canal and obstruction by cerumen	Given the technical issues and the moderate correlation with the core temperature (0.77),[22] tympanic thermometry is not reliable in critically ill patients[22,31]
Rectal	Tip of the temperature probe should be 4 cm in the rectum as the temperature increases by 0.8° C for every 2.5 cm	Lags behind core temperature recording. Not useful for rapid temperature recording Discomfort and potential risk of perforation. Accurate recording affected by feces and inflammation	Significant lag during rapid temperature changes[32] when compared with other core sites. Does not perform as well as urinary and the esophageal temperatures[27] not recommended in the critically ill
Axillary	Placement in central position with arm adducted-traditionally mercury thermometers must be kept for 5-10 min Digital thermometers specific to the axilla may either give a quick calculated temperature or a measured temperature after 5 min of placement in the axilla	Could be affected by sweating, ambient temperature, incorrect placement of probe, and correct timing	Although used widely, concordance with core is only modest with variability of 0.27°±0.45°C[27,36,37] Not recommended for temperature monitoring in the critically ill

PA: Pulmonary artery, NG: Nasogastric

2. Electrical devices – These use thermistors, thermocouples, or resistance thermometers. PA, esophageal, nasopharyngeal, and bladder temperature monitors use thermistors. Even though thermistors need calibration, they have better accuracy and precision than thermocouples. Resistance thermometers are not very sensitive and are based on the principle that the resistance of the metal increases with increase in temperature
3. Infrared devices – This technology, used in tympanic thermometers, work on the principle that radiation (heat) is converted into an electrical signal. These devices, even though widely popular, do not reliably reflect core temperatures
4. Single- or multi-use chemical thermometers have some accuracy issues for clinical use[40] and are hence not recommended.

In ICUs, electrical devices using thermistors are recommended for the reasons documented above.

Conclusions

It is important to closely monitor, manipulate, and regulate temperature in the critically ill to minimize the physiological and biochemical ill-effects of extremes of temperature. In the ICU, based on the evidence provided above, core temperature monitoring using either urinary, nasopharyngeal, or esophageal temperatures is recommended. One needs to be aware of the pitfalls and fallacies of other commonly used sites.

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Conflicts of interest

There are no conflicts of interest.

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