Getting to the core: Considerations for Perioperative Temperature Monitoring
Disclosure

Sponsored by 3M Health Care
Presented by: Jamie Dougherty, BSN, RN
Clinical Specialist – OR Solutions
Medical Markets Division
Learning Objectives

1. Discuss the importance of monitoring core body temperature in perioperative patients.

2. Identify methods of monitoring body temperature during the perioperative journey and the benefits and drawbacks associated with each method.

3. Describe zero-heat-flux technology and summarize associated clinical studies.

4. Outline guidelines and recommended practices for perioperative temperature monitoring.
Why temperature monitoring?

Temperature is one of the four main vital signs that is monitored to help provide safe and effective care.

1. Temperature
2. Pulse
3. Respiratory rate
4. Blood pressure
Temperature

An important vital sign for the surgical patient

• Accurate core body temperature monitoring is vital and will identify if the patient is hypothermic, normothermic, or hyperthermic
• Patients undergoing anesthesia are at risk for inadvertent perioperative hypothermia
• Fever detection is critical and can warn of infection, allergic reactions, mismatched blood transfusions or other complications
• Accurate temperature monitoring will indicate whether warming interventions are effective
• Important to ensure that temperatures post operatively are accurate as they have patient care implications and potential financial consequences
Malignant Hyperthermia (MH)

- Rare but serious risk of general anesthesia
- Failure to detect and treat MH increases the likelihood of complications, including cardiac arrest and death\(^4\)
- Changes in core temperature can assist in diagnosis

Inadvertent Hypothermia

Occurs in up to 90% of patients, unless treated and is considered a frequent, preventable complication of surgery.

Negative outcomes of inadvertent perioperative hypothermia

Perioperative hypothermia is defined as core temperature less than 36.0°C. Research shows that even mild hypothermia can result in significant negative outcomes including:

- Increased Rate of Wound Infection
- Increased Mortality Rates
- Coagulopathy
- Prolonged & Altered Drug Effect
- Myocardial Ischemia & Cardiac Disturbance
- Shivering & Thermal Discomfort
- Delayed Emergence from Anesthesia

Core temperature

• The temperature of vital organs deep within the body, as opposed to peripheral temperature of the limbs

• Single best indicator of thermal status

• Measured in perioperative patients to monitor inadvertent perioperative hypothermia, response to warming, detect malignant hyperthermia, surgical site infection or transfusion reaction

• Anesthesia impairs ability to regulate core temperature

Thermoregulation: Under Normal Circumstances

The body’s normal response to temperature (°C)

- Vasoconstriction
- NST
- Shivering
- Vasodilation
- Sweating

0.2°C Interthreshold Range


Thermoregulation: Under Anesthesia

4.0°C Interthreshold Range

Vasoconstriction
NST

Vasodilation
Sweating

Hypothermia: < 36.0°C

Anesthesia-impaired response to temperature (°C)


Heat redistribution during anesthesia

Warmer blood from the core moves to the periphery

Cooler blood in the periphery mixes with warmer blood from the core

This mixture and flow of blood reduces core body temperature

Characteristic Patterns of General Anesthesia-Induced Hypothermia

- Core temperature can drop 1.6°C in the first hour of general anesthesia\(^1,2\)
- 81% of this temperature decrease is due to core-to-peripheral heat redistribution\(^2\)

Regional Anesthesia

- Patients undergoing regional anesthesia are also at risk for hypothermia\textsuperscript{5,7,8}
- Temperatures often are not routinely monitored\textsuperscript{7,9}
- Patient may be asymptomatic
- Patients often feel warmer due to incorrect perceptions in blocked areas\textsuperscript{5}
- Hypothermia often undetected\textsuperscript{9}

How is temperature monitoring being done today?
Numerous temperature monitoring methods

- Axilla
- Esophageal
- Oral (Sublingual)
- Temporal Artery Scanner
- Tympanic Membrane
- Nasopharyngeal
- Pulmonary Artery
- Bladder
- Rectal

Accuracy and Invasiveness:
- Least Accurate, Least Invasive: Skin Sensor Probe
- Least Accurate, Invasive: Nasopharyngeal
- Invasive: Esophageal, Rectal
- Most Accurate, Least Invasive: Axilla, Oral
- Most Accurate, Most Invasive: Tympanic Membrane

Suitability:
- Suitable for OR use, typically compatible with general anesthesia: Tympanic Membrane, Axilla, Temporal Artery Scanner
- Suitable for regional anesthesia pre-op and PACU, estimates body temperature: Oral, Nasopharyngeal
Choosing Methods of Temperature Measurement

✓ Accurate, reliable and precise across all possible temperature ranges
✓ Not sensitive to outside influences
✓ Safe
✓ Determined by accessibility of site, ease of use and patient comfort
Temperature monitoring devices

- Wide variations can exist due to method and technique
- Several things can affect the accuracy of a temperature reading:
  - Improper technique
  - Reliability of the instrument
  - Not using the proper thermometer in the proper place
  - Not following the manufacturers instructions for use
Oral

**Limitations**

- Accuracy impacted by technique, probe placement
- Not ideal for all surgical patients, unconscious or restless patients
- Intermittent readings

**Advantages**

- Quick, easy, familiar to patients
- Reasonable estimation of core body temperature

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Bladder

**Limitations**

- Invasive
- Accuracy diminishes with core temperature changes\(^1\), hypothermia\(^3\), and is influenced by urine output\(^2\)

**Advantages**

- No variation due to technique
- Reasonable estimation of core temperature
- Continuous

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Axillary

Limitations

• Consistently varies from core temperature\(^1\)
• Placement of probe highly variable; decreases precision of measurement\(^1,3\)
• Not an accurate reflection of core temperature with hypothermia or vasoconstriction\(^2\)

Advantages

• Non-invasive, safe
• Somewhat protected from ambient air with proper placement

References:
Rectal

Limitations

• Insertion can be uncomfortable for awake patient
• Positioning patient can be difficult
• Accuracy may be impacted by presence of stool\(^3\)
• May not be appropriate for patients with thrombocytopenia
• Lag behind with thermal change\(^1-3\)
• Poor at detecting malignant hyperthermia\(^1\)

Advantages

• Accurate reflection of core temperature at steady state
• Continuous

References:
Infrared Aural Canal (Tymppanic)

Limitations

• Proper placement difficult to achieve consistently
• Errors in measurement technique may contribute to accuracy and reliability of measurements\textsuperscript{1,2}
• Not in close enough proximity to tympanic membrane to obtain and evaluate the infrared signal
• Numerous studies have evaluated the accuracy and variability of this monitoring method and have deemed infrared tympanic thermometers insufficient for clinical use\textsuperscript{1,3-7}

Advantages

• Quick
• Easy
• Non-invasive

Skin Probes

**Limitations**

**LCD**
- Found to be inadequate for measuring trends in core temperature\(^1,5-8\)
- Accuracy may be impacted by ambient temperature, air flow at sensor\(^4,7-9\)
- Not recommended for detection of MH\(^2\)
- Unsuitable for clinical use\(^3\)

**Thermocouple/Thermistor**
- Sensitive to ambient temperature and airflow\(^4,9-10\)
- Accuracy decreases as core temperature decreases\(^3\)
- Unsuitable for clinical use\(^3\)

**Advantages**

**LCD & Thermocouple/Thermistor**
- Easy to use and observe, convenient to place, noninvasive, single patient use

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Temporal Artery

Limitations

- Technique significantly impacts accuracy and precision of measurements\(^1,2\)
- Diaphoresis and airflow near the face may affect temporal artery measurements\(^1\)
- Improper cleaning of the lens can result in interference from buildup of oil and impact accuracy of readings\(^2\)
- Poor at detecting fever\(^5,6\) and hypothermia\(^4,7\)
- High reproducibility error\(^6\)
- Numerous studies found it insufficient for use in perioperative patients\(^6,7\) and clinical practice\(^3-5,8\)

Advantages

- Quick
- Easy
- Non-invasive

Zero-Heat-Flux Thermometry

Limitations
- Placement limited to forehead
- May not be appropriate for all patients and procedures

Advantages
- Non-invasive, accurate reflection of core temperature\(^1\)
- Continuous
- Easy to use
- Consistent (data travels with patient)
- Displays two hour temperature trend
- Electronic health record (EHR) compatible
- Reduces variability of multiple devices and techniques

How does Zero-Heat-Flux technology work?
How does it work?

Under normal conditions, heat moves from the warmer core out to the cooler periphery where it dissipates from our skin into the environment.
How does it work?

Zero-heat-flux creates a zone of perfect insulation allowing the warmer temperature to rise to the skin surface where the core temperature can be measured noninvasively.
How does it work?

• Consists of a single-use patient sensor applied to the forehead and control unit that displays temperature

• Accurate and precise in clinical studies
Clinical Studies
Clinical Studies

Observational study comparing core temperatures measured with a pulmonary artery catheter and non-invasive zero-heat-flux sensor

- 105 patients undergoing nonemergent cardiac surgery, excluding the period of cardio pulmonary bypass (CPB)

**Results:**
- 36,000 data pairs
- Mean error (TZHF-TPA) = -0.23°C; 95% LOA= ±0.8°C

Conclusion

Core temperature can be measured non-invasively with zero-heat-flux technology.
Clinical Studies

Prospective, observational study

Temperatures measured simultaneously

- Lower Extremity Vascular Surgery: Non-invasive zero heat flux (ZHF) temperature sensor and esophageal
- Cardiac Surgery: Non-invasive ZHF temperature sensor and nasopharyngeal and pulmonary artery

Results

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Mean Difference (°C)</th>
<th>(95% limits of agreement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZHF vs. Esophageal</td>
<td>+0.08°C</td>
<td>-0.25 to +0.40°C</td>
</tr>
<tr>
<td>Vascular Surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZHF vs. Pulmonary Artery</td>
<td>-0.05 °C</td>
<td>-0.56 to +0.47°C</td>
</tr>
<tr>
<td>Cardiac Surgery (Off CBP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZHF vs. Nasopharyngeal</td>
<td>-0.12 °C</td>
<td>-0.94 to +0.71°C</td>
</tr>
<tr>
<td>Cardiac Surgery (On &amp; Off CBP)</td>
<td></td>
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</tr>
</tbody>
</table>

Conclusion

This study demonstrated agreement with core body temperatures measured using the non-invasive zero-heat-flux temperature sensor comparable to esophageal, nasopharyngeal and pulmonary artery with temperatures ≥34°C.
Clinical Studies

Prospective study

Compared zero-heat-flux (ZHF) thermometry to esophageal and arterial temperature using a femoral artery catheter in ICU and Neuro ICU patients.

Results:

>62,000 pairs of temperature were collected

Conclusion

The core temperature measured by the ZHF method provides a comparable reliability to esophageal or arterial temperatures in ICU patients.
Clinical Studies

Comparative study

Pediatric patients undergoing non-emergent urology, orthopedic or general abdominal surgery

Results:

Average bias between the ZHF and nasopharyngeal temperatures was small at 0.28°C.

Conclusion

The non-invasive method helps to reduce or eliminate the disadvantages associated with nasopharyngeal temperature monitoring including placement technique, patient discomfort, risk of injury, cross-contamination and inconsistent methodologies across departments.
Guidelines and Recommended Practices
American Society of Anesthesiologists (ASA)

Basic Anesthetic Monitoring

• “During all anesthetics, the patient’s oxygenation, ventilation, circulation and temperature shall be continually evaluated.”¹

• “Every patient receiving anesthesia shall have temperature monitored when clinically significant changes in body temperature are intended, anticipated or suspected.”¹

Postanesthetic Care

• “Routine assessment of patient temperature detects complications, reduces adverse outcomes, and should be done during emergence and recovery”²

• “Patient temperature should be periodically assessed during emergence and recovery.”²


Standard V – Thermoregulation

• “When clinically significant changes in body temperature are intended, anticipated, or suspected, monitor body temperature in order to facilitate the maintenance of normothermia.”
Temperature Measurement Recommendations Supported by Strong Evidence

• “Near-core measures of oral temperature best approximates core” (Class I, Level B)

• “The same route of temperature measurement should be used throughout the perianesthesia period for comparison purposes” (Class I, Level C)

• “Caution should be taken in interpreting extreme values from any site with near-core instruments” (Class I, Level C)

Recommendation II

• The same method of temperature measurement should be used throughout the perioperative period when clinically feasible (High Evidence)

• The method of temperature monitoring should be selected based on the requirements of the procedure such as accessibility of the route, invasiveness of the route, anesthesia type, anesthesia delivery method.

• Temperature may be measured using core temperature sites: tympanic membrane (via thermistor), distal esophagus, cutaneous (via zero-heat-flux thermometry), nasopharynx, pulmonary artery or “near-core” sites: mouth, axilla, bladder, rectum, skin, tympanic membrane (via infrared sensor)

1. AORN. Guideline for Prevention of Unplanned Patient Hypothermia. AORN, Inc. 2015.
Malignant Hyperthermia Association of the U.S.

• “MHAUS recommends core temperature monitoring for all patients given general anesthesia lasting more than 30 minutes.”

1.1.5 Temperature should be measured from a site that produces a direct measurement of core temperature or a direct estimate of core temperature

- These sites include: pulmonary artery catheter, distal esophagus, urinary bladder, zero heat-flux (deep forehead), sublingual, axilla, rectum

1.1.6 Do not use indirect estimates of core temperature in adults having surgery.

**Preoperative Temperature**

- The patient's temperature should be measured and documented in the hour before they leave the ward or emergency department.

**Intraoperative Temperature**

- The patient’s temperatures should be measured before induction of anesthesia and every 30 minutes until the end of surgery

**Postoperative Temperature**

- The patient’s temperature should be measured and documented on admission to the recovery room and then every 15 minutes.

Summary

• Accurate temperature measurement is critical to the assessment and management of perioperative patients

• Most of the invasive devices that accurately report core body temperature are limited to operating room use

• Most instruments are unable to accurately and noninvasively measure core temperature

• Improved accuracy with a consistent method may help compliance with quality measures and improve temperature management utilization

• Deep tissue thermometry utilizing zero heat flux technology can improve quality by noninvasively monitoring core temperature consistently and accurately throughout the perioperative journey, regardless of the type of anesthesia
Questions
Thank You