Disclosure

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3M Infection Prevention Division

Introduction

- Perioperative hypothermia is defined as any core temperature less than 36.0°C (96.8°F)
- Inadvertent perioperative hypothermia is considered a frequent, preventable complication of surgery
- Unless preventative measures are taken, inadvertent hypothermia occurs in 50% to 90% of surgical patients
- Research shows that even mild hypothermia can result in significant negative outcomes
Introduction

- The induction of anesthesia can cause a drop in patient core temperature of up to 1.6°C on average within the first hour.
- Even mild hypothermia can lead to adverse outcomes and additional costs.

Even mild hypothermia can lead to adverse outcomes and additional costs. Adapted from: Sessler, Anesth, 2000

Course Objectives

- Explain how the body’s thermoregulation system works
- Define unintended perioperative hypothermia
- Define and explain the principle mechanisms of heat loss in the surgical patient
- Identify adverse patient outcomes associated with unintended perioperative hypothermia
- Identify areas where cost savings can be recognized by maintaining normothermia
- Review the effectiveness of currently available warming modalities
- Explain the benefit of prewarming to help prevent unintended perioperative hypothermia
Normothermia

- Normothermia: the body’s ideal thermal state
- Core temperature: 37.0°C (98.6°F)
- Temperature gradient: 2-4°C between the core and periphery

Hypothalamus

- The hypothalamus regulates the body’s core temperature
- Thermoreceptors are used by the hypothalamus to respond to temperature
- Thermoreceptors are located in:
  - Skin
  - Spinal cord
  - Brain
  - Deep central tissues

Behavioral Changes to Body Temperature

- Behavioral changes to temperature are prompted by thermal discomfort
- Responses may include:
  - Adding or removing clothing
  - Adjusting ambient temperature
  - Moving to cooler or warmer areas
Surgical Patients' Response to Body Temperature

- Anesthetized surgical patients:
  - Cannot regulate temperature through behavior changes
  - Rely on body’s thermoregulation system - and clinician intervention - to regulate temperature

Interthreshold Range

- Interthreshold range:
  - Acceptable limits of core body temperature
- Body’s response to cold:
  - Vasoconstriction
  - NST
  - Shivering
- Body’s response to heat:
  - Vasodilation
  - Sweating

FACTORS CAUSING UNINTENDED HYPOTHERMIA
Primary Causes of Perioperative Hypothermia

Unintended Hypothermia:
Any core temperature <36°C (96.8°F)²

- Primary causes of perioperative hypothermia include:²³
  - Administration of anesthetic drugs leading to temperature redistribution
    - General anesthesia
    - Regional anesthesia
    - Cold O.R. temperatures
  - Exposed body cavities
  - Infusion of cold fluids and blood

General Anesthesia

- Patients cannot regulate their core temperature to the optimal set point under general anesthesia:³
  - Inability to rely on behavioral responses
  - Rely on autonomic thermoregulation system to respond
- Anesthetic agents inhibit the autonomic system by:³
  - Reducing metabolism
  - Depressing hypothalamus

Metabolic Heat Production

- 40-year-old (70kg) patient:²
  - Awake: 70 kilocalories/hour
  - Anesthetized: 42 kilocalories
- 80-year-old (70kg) patient:²
  - Awake: 60 kilocalories/hour
  - Anesthetized: 38 kilocalories

Adapted from: Morrison, International Anesthesiology Clinics, 1988
Anesthesia-Impaired Response to Temperature

- The hypothalamic response to regulate temperature is degraded.
- Interthreshold range widens to 4°C.
- Anesthetized patients get warmer or colder before thermoregulatory responses are triggered.

Heat Redistribution

- An average core temperature drop of 1.6°C can occur in the first hour of general anesthesia.
- 81% from core-to-peripheral heat redistribution known as redistribution temperature drop.

Characteristic Patterns of General Anesthesia-Induced Hypothermia

Adapted from: Sessler, Anesth, 2000
Phases of Unplanned Hypothermia

Phase I: Rapid decrease in core temperature
Phase II: Slow, linear decline in temperature
Phase III: Temperature plateau

Regional Anesthesia

- Similar process of hypothermia as compared to general anesthesia
- Central and peripheral thermoregulatory functions impaired
- Nerve blocks prevent normal responses and disrupt nerve conduction
- Skin temperatures in blocked areas misjudged by thermoreceptors

Regional Anesthesia

- Patients often feel warmer due to incorrect perceptions of thermoreceptors in blocked areas
- Hypothermia is frequently undetected in patients under regional anesthesia because:
  - Core temperatures are not monitored as frequently
  - Patients do not typically express feelings of thermal discomfort

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**Cold Environment**

- Heat loss exacerbated by cold environment in most O.R.s
- O.R. temperatures are 16.0-21.0°C (60.8-69.8°F)
- Heat moves from warmer to colder object or area

**Surgical Procedure**

- Heat loss due to surgical procedure
- During prep and surgery, large areas of skin are exposed to the cold O.R.
- Surgical incisions exposing internal organs also contribute

**Additional Causes of Heat Loss**

- Additional causes of unplanned perioperative hypothermia may include:
  - Length of surgery
  - Blood and fluid loss
  - Wet skin preps

Anesthesia is the primary cause of unintended hypothermia in surgical patients
Mechanisms of Heat Transfer

- **Radiation**: Heat loss to cold environment
- **Convection**: Heat loss from body surface into air currents
- **Conduction**: Heat loss due to contact with another object
- **Evaporation**: Heat loss from moisture on the body's surface changing from a liquid to a gaseous state

EFFECTS OF UNINTENDED HYPOTHERMIA

Adverse Effects of Unintended Hypothermia

- There are many documented adverse effects of unintended hypothermia including:
  - Wound infection
  - Myocardial ischemia and cardiac disturbances
  - Coagulopathy
  - Prolonged and altered drug effect
  - Increased mortality
  - Shivering and thermal discomfort
  - Delayed emergence from anesthesia
SSIs and Normothermia

- Improving patient safety and reducing surgical complications, such as SSIs, are an important focus for healthcare.
- Maintaining normothermia has been identified as a key contributor to reducing SSIs by various organizations.

The Numbers are Staggering

- Hospital infections, including SSIs, are the fourth largest killer in the U.S., claiming more lives than AIDS, breast cancer and traffic accidents combined.
- SSIs may result in yearly medical costs of $1 to $10 billion.
- Patients who acquire SSIs are more likely to be:
  - Readmitted to the hospital
  - Admitted to the ICU
  - Two times more likely to die

Surgical Wound Infections

- Hypothermic colorectal surgical patients with mild hypothermia have:

  ![Graph showing infection rate and length of hospital stay for hypothermic vs. normothermic patients.](image)
Myocardial Ischemia and Cardiac Disturbances

- Hypothermia contributes to an increase in morbid myocardial events and ventricular tachycardia.\(^1^\)

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Coagulopathy

- Blood loss is higher in hypothermic patients during surgery and postoperatively.\(^2^\)
- Even a core temperature drop of <2°C was found to increase blood loss by 500mL (1 unit).\(^2^\)

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Coagulopathy

- Increased allogeneic blood required for hypothermic patients.\(^2^\)\(^5^\)
- Hypothermia may:
  - Impair platelet function
  - Reduce clotting
  - Increase fibrinolysis

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Prolonged and Altered Drug Effect

- Drug metabolism is reduced by hypothermia.
- Vecuronium, a neuromuscular blocking agent, was found to have an average duration of:
  - 28±4 minutes in normothermic patients
  - 62±8 minutes in hypothermic patients

Increased Mortality

- Increase in morbidity and mortality rates postoperatively.
- The mortality rate for the hypothermia group was 12.1% versus a rate of 1.5% for the normothermic group.

Shivering

- Shivering occurs in 40-60% of unwarmed patients recovering from general anesthesia.
- Some patients have expressed the feelings of thermal discomfort and shivering to be more significant than post-surgical pain.
- It is rare to see intense shivering postanesthetically in patients with normothermic temperatures.
Thermal Comfort

- A study by Fossum, et al found that:
  - Thermal comfort is greater in actively warmed patients.  
  - No actively warmed patients verbalized being cold.  
  - 66% reported “most comfortable” on a comfort scale.

- Warmth is the top nursing concern, followed by pain management and position.
- Maintaining normothermia is important clinically and as a means of increasing patient comfort.

Delayed Emergence from Anesthesia

- Hypothermic patients need an average of 90 minutes longer in PACU vs. normothermic patients.
- Maintaining normothermia is likely to decrease PACU time.

[Graph showing recovery time differences between normothermic and hypothermic patients]

Adapted from: Lenhardt et al., Anesth, 1997

MAINTAINING NORMOTHERMIA: OUTCOMES AND ECONOMICS
Benefits of Normothermia

- Studies have suggested that maintaining normothermia may yield positive results such as:
  - Reduction in the use of blood products
  - Shortened length of stay
  - Decreased ICU time
  - Reduced rate of wound infection
  - Decreased likelihood of myocardial infarction
  - Lower mortality rates

Meta-Analysis Results

<table>
<thead>
<tr>
<th>Meta-Analysis Results</th>
<th>Cost Savings Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood products</td>
<td>$227 - $344</td>
</tr>
<tr>
<td>Hospital stay</td>
<td>$1,534 - $4,602</td>
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<tr>
<td>ICU time</td>
<td>$105 - $314</td>
</tr>
<tr>
<td>Wound infections</td>
<td>$549 - $1,897</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>$86 - $90</td>
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<tr>
<td>Mechanical ventilation</td>
<td>$16 - $26</td>
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<tr>
<td>Mortality</td>
<td>Undefined</td>
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<tr>
<td>Total Per Patient Savings</td>
<td>$2,495 - $7,073</td>
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</tbody>
</table>

Adapted from: Mahoney, Odom, AANA Journal, 1999

UK Clinical Practice Guideline

<table>
<thead>
<tr>
<th>UK Clinical Practice Guideline Consequences</th>
<th>Unit cost (GBP)</th>
<th>Unit cost (USD)</th>
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<tbody>
<tr>
<td>Surgical wound infection (minor surgery)</td>
<td>£950</td>
<td>$1,508</td>
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<tr>
<td>Surgical wound infection (major surgery)</td>
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<tr>
<td>Transfusion</td>
<td>£244</td>
<td>$387</td>
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<tr>
<td>Mortal cardiac event (ischemia)</td>
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<td>$3,213</td>
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<td>Mortal cardiac event (cardiac arrest)</td>
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<td>Mortal cardiac event (myocardial infarction)</td>
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<td>Hospital length of stay per hour</td>
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</table>

1 GBP=1.58755 USD (1/26/11) Source: www.xe.com

Adapted from: NICE, Clinical Practice Guideline, 2008
Modalities for Warming

- There are a variety of warming modalities:\n  - Heated humidifiers
  - Heated moisture exchangers
  - Warm cotton blankets
  - Thermal drapes
  - Circulating water mattresses
  - Electric conductive pads and covers
  - Forced-air warming
  - Fluid warming

**GOAL:**
Maintain patient core temperature (≥36°C)

Active Warming vs. Passive Warming

- It is important to understand the differences between active warming and passive warming.
- Active warming is the active application of heat, i.e. forced-air warming or conductive warming.
- Passive warming uses insulative techniques, i.e. cotton blankets or surgical drapes.
- Active warming with forced-air warming is referenced as the standard of care for managing perioperative normothermia.\textsuperscript{22-25}
Relative Effectiveness

Forced-air warming is the most effective method for maintaining normothermia.\(^{21}\)

Airway Heating and Humidification

- Less than 10% of heat is lost through the respiratory tract, making airway heating minimally effective.\(^{6, 21-22}\)

Cotton Blankets

- Cotton blankets are passive insulators – they do not provide active warming.\(^{26}\)
- Heat from a warmed cotton blanket is quickly lost to its surroundings.\(^{26}\)
- Patient heat loss is virtually identical with warmed and unwarmed cotton blankets.\(^{26}\)
Conductive Warming

- There are various conductive warming methods such as:
  - Circulating water mattresses
  - Warm water garments
  - Resistive electric covers
  - Heated pads
- Conductive modalities are designed to be in direct contact with the patient’s skin to improve heat transfer from the device to the patient.
- Heat is provided where there is surface-to-surface contact.

Circulating Water Mattresses

- Heat moves from warm mattress to colder body with surface-to-surface contact.
- Heat transfer effectiveness is limited to:
  - The relatively small body surface area in contact with the mattress
  - Surface contact areas that are typically poorly perfused
- Combination of heat and pressure can increase potential for thermal injury.

Resistive-Electric Modalities

- Recent studies on the effectiveness of resistive-electric warming modalities versus forced-air warming have found:
  - Combined use of two resistive-electric blankets (both over-the-body and under-the-body) produced non-inferior core temperature results after elective orthopedic surgery when compared to a single forced-air warming upper body blanket.
  - Patients warmed with a forced-air full body blanket were re-warmed two times faster than a resistive-electric full body warming blanket following major maxillary tumor surgery.
Forced-Air Warming

- Effective due to convection and radiation
  - Heat transfer is due to the gentle dispersion of warmed air across the patient's skin
  - Forced-air blankets transfer more heat while operating at a relatively low temperature
- Forced-air warming has been found to be the most effective warming therapy.

Forced-Air Warming

- Forced-air warming provides effective warming therapy, even when only 50% of the patient's body surface is covered during surgery.

Forced-Air Warming Effectiveness

- In a study by Ouellette:
  - Patient with forced-air warming maintained temperatures ≥36.2°C
  - Temperatures were maintained even with <50% patient body surface covered
Advances in Forced-Air Warming Systems

- Under-the-body blankets are a recent advance in forced-air warming systems.
- Under-the-body blankets are used during procedures requiring full-access to the patient, or where traditional over-the-body blankets cannot be used.

Forced-Air Warming: Clinical Evidence

- Nearly 170 studies published on the safety and effectiveness:
  - Including >60 randomized controlled trials.
- Forced-air warming is the only patient warming modality with peer-reviewed clinical outcomes data proving effectiveness in maintaining normothermia resulting in a reduction of SSIs.

Facts about Forced-Air Warming

- A summary of clinical evidence:
  - Numerous studies show forced-air warming does not increase bacterial contamination of O.R.
  - Huang, et al. found a decrease in bacterial count at the surgical site when forced-air warming was used.
  - Olmsted, et al. found forced-air warming had no negative effects on air quality in the O.R.
  - Single-use, disposable blankets reduce the risk of cross-contamination.
  - No infection has ever been linked to the use of a forced-air warming system.
Fluid Warming

- Helps prevent hypothermia as an adjunct warming therapy
- Generally does not transfer enough heat to increase patient temperature
- Prevents additional patient cooling caused by cold blood or IV solutions

Infusing cold fluids can produce hypothermia in surgical patients. Each liter of fluid infused at ambient temperature (or blood at 4°C) can decrease the mean body temperature by about 0.25°C.

Water Bath vs. Dry Heat Fluid Warming Systems

**Water Bath Fluid Warming Systems**
- Use warm water to transfer heat
- Water has been identified as a potential source of nosocomial pathogens
- Potential source of bacteria growth when not properly maintained

**Dry Heat Fluid Warming Systems**
- Use warming cassettes inserted between metal warming plates
- Eliminate potential source of nosocomial pathogens because no water is used
Definition of Prewarming

- Prewarming is the application of heat prior to surgery for the purpose of increasing the total heat content of the body.
- Prewarming can increase the temperature of the periphery, which means that the temperature gradient within the body’s core is reduced.

Prewarming and Heat Redistribution

- Core temperature drop happens too quickly for active warming to compensate during the first hour following anesthesia induction. In essence, the ability to maintain normothermia in the O.R. depends on the length of surgery and the time required to “re-warm” following temperature drop.
Prewarming Benefits

- 30-60 minutes of prewarming with forced-air warming can “bank heat” in the periphery and reduce or eliminate redistribution temperature drop. It is not possible to clinically warm patients with warmed I.V. fluids alone.

Prewarming with active forced-air warming is the only practical way to offset redistribution temperature drop.

QUALITY IMPROVEMENTS: PATIENT NORMOTHERMIA AND SSI

Focus on SSI Reduction

- Surgical site infections (SSI) are costly and prevalent
  - 90-day costs of $86,633 per patient with an SSI, while surgeries without adverse events average just $18,284.
  - Preventing each infection can result in a reduced length of hospital stay of up to one week, and savings of $3,151 on average.
  - SSIs represent 40% of all hospital-acquired infections in surgical patients.
Normothermia and SSI Reduction

“There is no longer a question whether maintenance of normal core body temperature is important for decreasing the incidence of SSI; the answer is unequivocally yes.”


Best Practices for Preventing SSIs

- Clipping
  - Remove hair appropriately
- Antibiotics
  - Use prophylactic antibiotics appropriately
- Temperature
  - Maintain normothermia
- Sugar
  - Maintain glucose control

Rationale for Normothermia Measures

- Scientific literature is strong
- The practice gaps are substantial
- Effective management is inexpensive, low risk, and easy to implement
- The most commonly used warming systems are remarkably safe

“There are few, if any, anesthetic interventions that have been proven to so markedly improve the outcome of surgery with so little effort, risk, and cost, making this a nearly ideal area for performance measurement and improvement.”

Normothermia: An Important Topic

Proven Method of Warming
- Forced-air warming is included in pay-for-performance quality measures.47-48
- Forced-air warming is the standard of care in preventing unintended hypothermia and its consequences.22-25,49-50

CMS SCIP-Infection-10 Perioperative Temperature Management Measure51
- Active warming used intraoperatively – OR –
- At least one temp ≥36.0°C within 30 minutes immediately before or 15 minutes immediately after anesthesia end time
- All patients undergoing surgical procedures under general or neuraxial anesthesia of 60 minutes or longer
CMS SCIP-Infection-10 Perioperative Temperature Management Measure

What this means for facilities:
1. Warming more patients – regardless of age
2. Warming more procedures* – regardless of complexity
3. Ensuring normothermia

Normothermia is the goal

*Excludes cardiac bypass procedures

CONCLUSION

Conclusion

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Questions?

References

References


32. Hall AC, Teenier T. Bair Hugger does not increase microbial contamination in the Operating Room. 1991; PGA poster presentation.


