Preventing Complications of Inadvertent Perioperative Hypothermia in Older Adults Undergoing Total Joint Arthroplasty

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Learning Objectives
Participants will be able to:
1. List 3 risk factors for inadvertent perioperative hypothermia (IPH)
2. List 3 causes of IPH
3. Explain the mechanism of thermoregulation
4. Assess ways to prevent IPH using common warming devices

INTRODUCTION
Adults aged 65 years and older routinely undergo surgery for total joint arthroplasty under regional or general anesthesia. Hypothermia is a major complication of surgery and anesthesia in older adults. Inadvertent hypothermia in the perioperative area is a common phenomenon in surgical patients of all ages. This educational course is a literature review focusing on the mechanism of thermoregulation and inadvertent hypothermia in older adults for the purpose of deriving policies, procedures, and interventions to prevent inadvertent hypothermia in these patients.

Hypothermia in the perioperative area is defined as a core body temperature of less than 36°C (96.8°F). Hypothermia continues to be a major complication of surgery and anesthesia in surgical patients; its incidence ranges from 50% to 90%. Although hypothermia may be desirable for some cardiac and cerebral procedures, it is undesirable for most surgical patients and can result in negative consequences. Older orthopedic patients undergoing total joint replacement are at increased risk for complications associated with inadvertent hypothermia.

Background
Inadvertent perioperative hypothermia (IPH) is a well-documented problem in older surgical patients. The World Health Organization (WHO) and most developed countries use a chronological age of 65 years and older to define older adults. The US Census Bureau and the National Institute on Aging also describe older adults as those aged 65 years and older. Total knee replacement surgeries in this population, specifically, adults aged 65 to 84 years, have increased by 89% and total hip replacement surgeries have increased by 73%. The older adult population is forecast to double by 2031 and to make up 18% to 21% of the total population. This suggests that even more older patients will be undergoing surgery and will be exposed to the risk of inadvertent hypothermia. Physiological changes associated with increased age produce challenges related to hypothermia and shivering, including altered tissue oxygenation, impaired platelet function, increased pain, and increased oxygen demand.

Search Methodology
The PubMed (US National Library of Medicine), MEDLINE (US National Library of Medicine), Cumulative Nursing & Allied Health Literature (CINAHL; EBSCO Health), EBSCOhost (EBSCO Industries, Inc), and Google Scholar (Google Inc) databases were searched using the key words “hypothermia,” “elderly,” “total joint arthroplasty,” “general anesthesia,” “regional anesthesia,” “fluid warmers,” and “forced-air warmer.” The search was limited to a 10-year publication period from 2006 to 2016. Initially, titles, abstracts, and conclusions were screened to determine their significance and 20 articles were selected. The search was later expanded to a 20-year publication period starting from 1996 because of a lack of articles relevant to spinal anesthesia and hypothermia. The literature review was limited to 24 publications based on their relevance to the subject matter and inclusion criteria. Inclusion criteria were meta-analysis studies, quality improvement studies, and practice guidelines and recommendation studies. Studies not focused on older adults, hypothermia, total joint arthroplasty, fluid warmers, or forced-air warmers were excluded.

Literature Review
Mechanism of Thermoregulation
The hypothalamus is the thermoregulatory center of the body. It is responsible for maintaining normothermia and for regulating heat production and heat loss in the body. General and regional anesthesia interfere with the thermoregulatory function of the hypothalamus by inhibiting centrally mediated vasoconstriction and peripheral vasodilation, thereby causing hypothermia. The temperature of the blood circulating around major organs (heart, brain, and lungs) is called the core temperature; hypothermia is a fall in core body temperature below 35°C. Core temperature is measured in the pulmonary artery; it can also be measured via the esophagus, nasopharynx, or tympanic membrane. Axillary, skin, oral, rectal, or bladder measurements of temperature can be used to estimate core temperature. During general anesthesia, the temperature is measured via the esophagus, bladder, or rectum. These techniques, however, are invasive and unhygienic. Hypothermia is classified as mild, moderate, and severe.

Nunney classified mild hypothermia as around 31°C to 35°C, moderate hypothermia as around 29°C to 31°C, and severe hypothermia as any temperature below 29°C. Feinstein and
Miskiewicz\textsuperscript{11} defined mild hypothermia as a core temperature below 36°C to 34°C, characterized by confusion, shivering, amnesia, and normal pulse and blood pressure readings. These symptoms may easily be mistaken for something else in the post-anesthesia care unit (PACU). As also reported by Feinstein and Miskiewicz, moderate hypothermia is a core temperature below 33°C to 30°C, characterized by pupillary dilation and EKG changes, especially atrial fibrillation.\textsuperscript{11} A core temperature below 30°C is considered severe hypothermia, the consequences of which are hypotension, ventricular fibrillation, asystole, and eventually death. Judicious temperature monitoring throughout the perioperative area is thus important in the detection and prevention of hypothermia.\textsuperscript{11}

**Risk for Hypothermia**

Sieber and Barnett\textsuperscript{2} enumerate several physiologic changes in older patients that put them at increased risk for developing hypothermia during surgery. These notable changes in older adults include impaired thermoregulation and decreased metabolic activity because of decreases in muscle mass and fat distribution.\textsuperscript{11} A decreased metabolic rate and increased vasodilation cause heat loss by radiation and convection.\textsuperscript{3} Altered shivering threshold and impaired vasoconstriction due to decreased circulatory function with increased vascular stiffness put older adults at risk for hypothermia. Chronic diseases such as high blood pressure, bradycardia, and diabetes create a conduction abnormality predisposing older adults to hypothermia.\textsuperscript{11} Hooven\textsuperscript{2} also identified patients with hypothyroidism, diabetes, cardiac diseases, burns, cachexia, stroke, Parkinson disease, and trauma to be susceptible to hypothermia. Other factors include changing into thin, open gowns for surgery and food and fluid restriction for at least an 8-hour period, which cause a reduction in metabolism and a decrease in heat production and poor perfusion.\textsuperscript{12} Induction of general anesthesia is the single greatest risk factor for inadvertent hypothermia. The effect of anesthesia on body temperature is greatest in the first hour after induction.\textsuperscript{12} Environmental factors such as the operating room (OR) laminar flow, which allows several air exchanges per hour, can cause hypothermia by convection.\textsuperscript{12} OR personnel decrease the OR temperature to be more comfortable under the surgical lights, scrubs, caps, and masks. Cool antiseptic skin preparations and surgical incisions also increase heat loss.\textsuperscript{12}

**Causes of Hypothermia**

Kim et al\textsuperscript{11} presented several factors responsible for perioperative hypothermia in surgical patients. Both general and regional anesthesia interfere with thermoregulation. In spinal anesthesia, a conduction blockade interferes with temperature regulation in the body by inhibiting vasomotor and shivering responses and by redistribution of heat from the core of the body to the periphery.\textsuperscript{3} The inhibition of vasomotor and shivering responses and the redistribution of body heat due to spinal anesthesia predispose older adults to hypothermia.\textsuperscript{13} The tendency for patients to be awake during spinal anesthesia decreases the chance for core temperature monitoring, and patients may also state that they are warmer than they actually are.\textsuperscript{1} Concurrent administration of drugs such as propofol, meperidine, or morphine with spinal anesthesia increases vasodilation and risk for hypothermia.\textsuperscript{6} The type of surgery and its length have been shown to place patients at risk for hypothermia. Major surgeries such as total hip replacements, large open bowel surgery, and prolonged surgery times greater than 60 minutes promote heat loss because the body and internal organs are exposed to the cold environment for a lengthy period. Body temperature decreases in the first 40 to 60 minutes after anesthesia.\textsuperscript{12} When the OR temperature is set below 21°C, patients are at an increased risk for hypothermia because of heat loss through radiation, conduction, convection, and evaporation.\textsuperscript{1} Radiation and convection are the main contributing factors to heat loss and account for 85% of perioperative heat loss.\textsuperscript{6} Heat loss through radiation, which accounts for 60% of heat loss, occurs as heat is lost in the colder OR. In convection, body heat is lost to the cold environment; convection accounts for 12% of heat loss. When the patient encounters the cold OR table, when room temperature fluids are infused, or when cold blood products are transfused, heat loss occurs through conduction. Conduction accounts for 3% of heat loss. The exchange of anesthetic gases and oxygen during respiration and the use of alcohol-based skin preps account for evaporation heat loss.\textsuperscript{14} Evaporation has been shown to be alleviated by using humidified gases and oxygen.\textsuperscript{1}

**Effects of Hypothermia**

Hypothermia has a negative effect on the cardiovascular, neurologic, hematologic, and respiratory systems and depresses metabolic activities.\textsuperscript{11} Hypothermia puts stress on the cardiovascular system owing to the body’s vasoconstrictive response. Patients who are hypothermic develop high blood pressure as a result of the increased production of norepinephrine.\textsuperscript{15} Life-threatening arrhythmias such as bradycardia, atrial fibrillation, ventricular fibrillation, and eventually asystole occur with hypothermia.\textsuperscript{11} Sieber and Barnett\textsuperscript{2} stated that whenever the core body temperature decreases by 1°C, the body responds with shivering, which in turn increases the heart rate and blood pressure, thereby stressing the cardiovascular system even more. Increased coronary resistance reduces coronary perfusion and puts patients with heart disease at risk for myocardial infarction.\textsuperscript{11} Feinstein and Miskiewicz\textsuperscript{2} noted that hypothermia is desirable during neurosurgical procedures because of its protective effects on cerebral tissues during decreased blood flow. The neuroprotective effects of hypothermia have been shown to cause irreversible neurologic damage to cerebral tissues because of decreased blood flow.\textsuperscript{11} It is recommended that hypothermia be used with caution during neurovascular surgeries to avoid damage to cerebral tissues.\textsuperscript{11} Coagulopathy and decreased platelet function associated with hypothermia have been demonstrated to increase blood loss during surgery.\textsuperscript{11} Evidence suggests increased potential for blood clots due to increased blood viscosity and peripheral vascular resistance associated with hypothermia, resulting in decreased blood flow to vital organs.\textsuperscript{16} Hyperventilation followed by hypoventilation occurs because of hypothermia. The oxyhemoglobin curve shifts to the left, causing hypoxia, anaerobic metabolism, and lactic acidosis.\textsuperscript{11} When shivering occurs, oxygen demand and carbon dioxide production increase and blood flow to the lungs decreases, with a subsequent decreased flow of blood and oxygen to all tissues and an increased risk of cardiac and respiratory events.\textsuperscript{7}
Hypothermia causes impaired wound healing; increases infection rates; increases blood losses, myocardial infarction, and pain response; and prolongs recovery time and hospitalization and ultimately hospital cost. Feinstein and Miskiewicz noted that patients who remain normothermic throughout the perioperative area have an overall better outcome.

**Devices Used to Prevent Hypothermia During Surgery**

Inadvertent hypothermia in the perioperative period is common. Several devices have been created to prevent hypothermia, such as body warming and fluid warming devices. The body warmers include the forced-air warmer, water-filled mattress, circulating water garments, radiant warmer, carbon fiber, resistive polymer blanket, electric heating pad, plastic garment, thermal exchange chamber, and circulating sleeve. Fluid warmers consist of insulated intravenous tubing, convective warming system, heated cylinder warming system, heated block warming system, heated element warming system, steel foil exchanger, water bath warming system, and the counter-current heated water system. Forced-air warmers are the most commonly used body warming system to prevent hypothermia. The forced-air warmers include the Bair Hugger system (3M), the Warmtouch system (Medtronic), the Thermacare system (Gaymar), and the WarmAir system (Cincinnati Sub-Zero). The forced-air warming systems have been documented to be effective and widely used in preventing hypothermia. The forced-air warmers prevent hypothermia by stopping convective and radiant heat loss from open and exposed skin and through heat transfer. The blanket property, the surface area covered, and the power unit determine the effectiveness of the forced-air warmers in preventing hypothermia. Sikka and Prielipp suggested that the use of forced-air warming devices can be a source of contamination and increased risk of surgical site infections in total joint arthroplasty. A surgical site infection is costly to the patient, hospital, and surgeon. Concerns exist that the use of forced-air warming devices disrupts the laminar flow of the OR and that potential pathogens growing in the hoses and filters might increase the risk for surgical site infection. Most surgical site infections are acquired through incision contamination by contaminated gloves or instruments during surgery. Muto et al conducted a study in the University of Pittsburgh Medical Center to determine the association between the forced-air warmer and surgical site infections in orthopedic cases. Those authors concluded that it is unlikely that forced-air warmers are associated with surgical site infections. Forced-air warming has been proven to be safe, effective, and commonly used in the prevention of IPH and does not increase the risk for surgical site infections.

The fluid warmers keep intravenous fluids heated by countercurrent heat exchange, water baths, convective air systems, insulators, and intravenous tubing passed through heated blocks. The efficacy of the fluid warmer depends on flow rate, volume of fluids, tubing length between the warmer and the patient, and the warming method used. Fluid warmers deliver fluid at temperature of at least 37°C. Warmed fluids do not actively warm a patient; however, infusing fluids below body temperature can cool down a patient significantly.

**Standards of Practice and Recommendations**

Preventing IPH is the goal of practice, and several health care organizations have developed guidelines for prevention. Countries such as the United Kingdom, Canada, Australia, New Zealand, and Sweden are taking initiatives to prevent hypothermia in surgical patients. The Centers for Medicare and Medicaid Services adopted a Surgical Care Improvement Project measure called SCIP-Inf-10 to prevent hypothermia in surgical patients. Currently, the reimbursement for services is tied to this SCIP measure. SCIP-Inf-10 is supported by the American Society of Anesthesiologists (ASA), the Association of periOperative Registered Nurses (AORN), the American Society of PeriAnesthesia Nurses (ASPN), the American College of Cardiology, the American Heart Association, and the Association for Professionals in Infection Control and Epidemiology. In the United Kingdom, the National Institute for Health and Care Excellence (NICE) published a guideline recommending the use of forced-air warmers and fluid warmers to prevent hypothermia. The Joint Commission in the United States agreed that hypothermia is deleterious to surgical patients and recommends that patients maintain normothermia during the perioperative period. The Centers for Disease Control and Prevention also noted that hypothermia increases the risk for infection. The implications of hypothermia are detrimental to the patient and the hospital. John et al recommend the use of more than one warming modality to combat the effects of hypothermia in the perioperative period. Hooven supported the use of both active and passive warming in preventing hypothermia.

**Conclusion**

The use of both a forced-air warming device and a fluid warmer is recommended for older adults undergoing total joint arthroplasty to prevent hypothermia in the perioperative period; however, no literature was found that addressed the effectiveness of the concurrent use of both modalities to prevent hypothermia in these patients. Future research is needed on the effectiveness of the concurrent use of both fluid warmers and forced-air warmers in preventing hypothermia in this patient population. The results of such research will prompt the development of an algorithm that will focus on evaluating risk factors to determine which older patients will benefit more in using both the fluid warmer and forced-air warmer to prevent inadvertent hypothermia.
References


Questions

POST TEST

1. All the following are common fluid warmers used in the operating room EXCEPT
   A. Heated block warming system
   B. Insulated intravenous tubing
   C. Electric heating pad
   D. Heated element warming system

2. Inadvertent perioperative hypothermia is defined as a core body temperature below
   A. 34°C (93.2°F)
   B. 36°C (96.8°F)
   C. 38°C (100.4°F)

3. The hypothalamus is the thermoregulatory center of the body.
   A. True
   B. False

4. Which of the following physiologic changes in older adults puts them at increased risk for hypothermia?
   A. Decrease in muscle mass
   B. Decrease in fat distribution
   C. All of the above

5. Core temperature can be measured through which of the following anatomic areas?
   A. Nasopharynx
   B. Tympanic membrane
   C. Esophagus
   D. All of the above

6. Severe hypothermia is defined as a fall in core temperature below which of the following?
   A. 30°C
   B. 33°C
   C. 35°C
   D. 36°C

7. Which of the following factors can cause inadvertent perioperative hypothermia?
   A. Surgery length over 60 minutes
   B. Operating room temperature above 21°C
   C. Small surgical incision
   D. All of the above

8. The temperature of blood circulating around the heart, brain, and lungs is called core temperature.
   A. True
   B. False

9. Forced-air warmers are not commonly used in the operating room to prevent hypothermia.
   A. True
   B. False

10. Which of the following conditions can increase the risk for inadvertent perioperative hypothermia?
    A. Diabetes
    B. Hypothyroidism
    C. Burns
    D. All of the above
11. The US Census Bureau classifies persons aged ______ years and older as older adults.
   A. 55
   B. 65
   C. 75
   D. 80

12. What is the single greatest risk factor for inadvertent perioperative hypothermia?
   A. Use of cool antiseptic skin preps
   B. Decrease in metabolism
   C. Induction of general anesthesia
   D. Wearing a thin operating room gown

13. Which of the following devices is a forced-air warming device?
   A. Bair Hugger system
   B. Water-filled mattress
   C. Circulating water garment
   D. Insulated intravenous tubing

14. Which health care organization published guidelines in 2008 recommending the use of forced-air and fluid warmers to prevent inadvertent perioperative hypothermia?
   A. American Society of Anesthesiologists (ASA)
   B. American Heart Association (AHA)
   C. Centers for Medicare and Medicaid Services (CMS)
   D. National Institute for Health and Care Excellence (NICE)

15. All the following are adverse effects of inadvertent perioperative hypothermia EXCEPT
   A. Increased heart rate
   B. Increased oxygen demand
   C. Lowered blood pressure
   D. Reduced blood flow to lungs

16. The hypothalamus is responsible for which of the following?
   A. Maintaining normothermia
   B. Regulating heat loss
   C. Regulating heat production
   D. All of the above

17. Which life-threatening arrhythmia can develop in hypothermic patients?
   A. Ventricular fibrillation
   B. Atrial fibrillation
   C. Bradycardia
   D. All of the above

18. Which of the following are the main contributing factors to heat loss in the operating room, accounting for 85% perioperative of heat loss?
   A. Radiation and convection
   B. Convection and evaporation
   C. Evaporation and radiation

19. How do general and regional anesthesia interfere with the function of the hypothalamus?
   A. Inhibit centrally mediated vasoconstriction
   B. Inhibit peripheral vasodilation
   C. All of the above

20. Which of the following factors has been shown to determine the effectiveness of the forced-air warmer in preventing perioperative hypothermia?
   A. Surface area covered
   B. Type of surgery
   C. Room air temperature
   D. All of the above