Risk Factors for Perioperative Hypothermia: A Literature Review

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Purpose: *The purpose of this article was to review the literature to identify risk factors for the development of unplanned perioperative hypothermia and to evaluate the strength of the evidence for each risk factor.*
Design: *Comprehensive literature review*
Methods: *An evidence rating scale was used to evaluate the strength and quality of the research gathered.*
Findings: *At this time, only anecdotal evidence is available to guide our efforts in the maintenance of perioperative normothermia. There is currently no strong evidence to implicate risk factors that do or do not cause a patient to develop unplanned perioperative hypothermia.*
Conclusions: *It is crucial to prevention that health care providers are able to identify risk factors and implement interventions. However, vigilance in the perioperative period can only enhance patient safety when we know what to look for. More research is needed to identify risk factors of unplanned perioperative hypothermia and effectively maintain normothermia throughout the perioperative period.*

Keywords: *perioperative hypothermia, core temperature, normothermia, monitoring, risk factors.*

HYPOTHERMIA, A CORE TEMPERATURE less than 36°C, that occurs inadvertently during surgery or anesthesia is known as unplanned perioperative hypothermia (UPH). UPH produces numerous negative outcomes, increases morbidity for surgical patients, and occurs in 50% to 70% of surgical patients.[1] A proactive approach to the maintenance of perioperative normothermia includes a thorough understanding of risk factors for the development of UPH, which can be identified during a preoperative anesthesia assessment. The purpose of this article is to provide a review of the physiology of thermoregulation, types of heat loss, effects of UPH, and current research regarding risk factors for the development of UPH. The evidence rating scale of Stetler and et al[2] was used to evaluate the strength and quality of the research supporting each risk factor and to determine if there was a need for further research regarding these risk factors.

Background

The human body is equipped to maintain a normal core temperature between 36°C and 38°C by balancing heat loss and heat gain. In the normal nonanesthetized patient, the hypothalamus—the thermostat of the body—regulates the core

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temperature hormonally, using information gathered from thermoreceptors in the hypothalamus, spinal cord, abdominal organs, and other central locations. Peripherally, thermoreceptors in the skin communicate to the hypothalamus.[3] The hypothalamus uses this core and peripheral temperature information to regulate body temperature through various methods. Sweating is implemented first, followed by vasodilation to cool the body. In the normal patient, shivering is a first line response to raise body temperature, although costly to the body via increased oxygen and caloric consumption. If shivering is not adequate, vasoconstriction is used to shunt heat to the core.[4] Vasoconstriction caused by hypothermia decreases blood flow, and thus oxygen and nutrients to tissues, reducing the immune response and increasing the risk for infection.[5] The increase in oxygen demand coupled with the decrease in blood flow resulting from shivering and hypothermia can potentially lead to myocardial infarction and death. Induction of anesthesia, whether by regional, neuraxial, or general anesthesia, impairs the body's thermoregulatory processes by shutting down the normal response of the body's thermoregulator, the hypothalamus.[6]

Mechanical methods of perioperative heat loss are well described: radiation, convection, conduction, and evaporation.[5,7] Radiation and convection account for 85% of heat lost in surgery, whereas conduction and evaporation account for only 15%. Radiation describes heat lost to the ambient environment, that is, to the cold operating room (OR), without the body touching another surface. With radiation, vasodilation brings body heat to the patient's skin surfaces and is lost to the cold ambient air temperature. Convection is heat loss to gas or liquid molecules, which occurs when liquids or gasses make contact with the patients' outer surfaces (skin or wound). This occurs with skin prep solutions and irrigation solution. Conduction is heat loss to a cold solid surface, such as an OR bed. Evaporation is the change from a liquid to a gas state. Evaporative heat loss in surgery can occur by exposed viscera or as the prep solutions or irrigation solutions dry.[5,7]

Numerous factors can predispose a patient to lose control of their body temperature during surgery. These factors will be discussed in this article. Although all risk factors are supported by weak or insufficient evidence, this literature review identified the following potential risk factors: cold ambient temperature, cold intravenous fluids and blood products, cold irrigation and skin preparation, body surface exposure, length of surgery, type of surgery, type of anesthesia, age, gender, comorbidities, hemodynamic status, body mass index, preoperative body temperature, and fluid shifts.

Stratification of risks for inadvertent perioperative hypothermia allows the anesthesia provider to diminish the negative impact caused by UPH. Multiple body systems including the respiratory, immune, cardiovascular, and adrenergic systems can be affected. Blood loss can increase as a result of hypothermia-induced coagulopathy, increasing a patient's need for blood transfusions. Muscle relaxation is potentiated, altering a patient's strength on emergence from anesthesia. Increased pain and uncomfortable shivering occurs with hypothermia. Shivering can cause metabolic disturbances such as increased oxygen consumption electrolyte and glucose abnormalities.[5] Henry's law tells us that hypothermia increases the solubility of gases, including volatile anesthetic gases. This causes anesthetic gases to remain trapped in the blood stream longer than normal prolonging emergence from anesthesia.[7] Many of these adverse outcomes of UPH can increase postanesthesia care unit or hospital length of stay with increased costs to the patient.[5] Any prophylactic steps taken to prevent UPH should enhance patient safety and prevent such undesired outcomes.

Methodology and Search Strategies

A comprehensive literature review was conducted to identify risk factors that correlated with the development of unplanned hypothermia in adult patients during the perioperative period. The authors independently searched for primary studies in the following databases: Medical Literature Analysis and Retrieval System online (Medline), Cumulative Index to Nursing and Allied Health Literature, and the Cochrane Library. Search terms used for all database searches included "hypothermia," "perioperative complications," and "risk factors." Articles considered were peer-reviewed

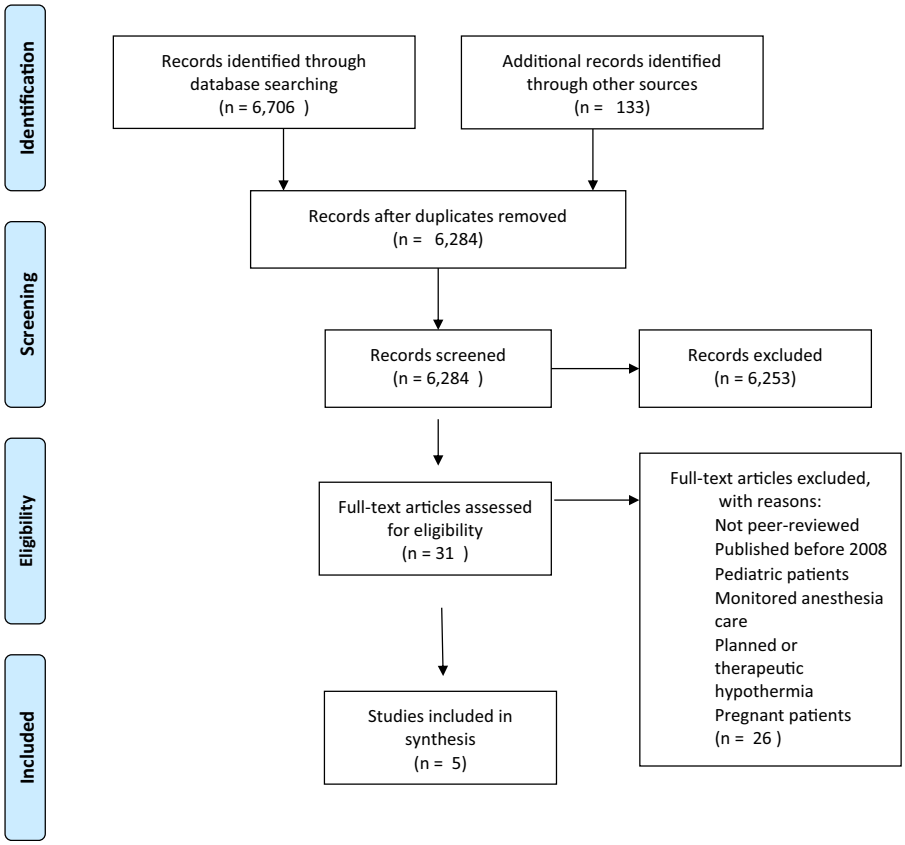

Figure 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) selection of articles for review (Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*. 2009;339:b2535). This figure is available in color online at www.jopan.org.

and published in a public forum between January 2008 and October 2015. The authors also checked the listed resources of any articles included in the literature review for additional sources of inclusion (Figure 1).

Thirty-one articles were retrieved and reviewed. Exclusion criteria included pediatric patients, pregnant patients, patients receiving monitored care anesthesia, and patients subjected to planned, advertent, or therapeutic hypothermia. After review, it was determined that 26 of the articles did not pertain to the research topic, which left 5 studies for inclusion that related to the topic of interest.

Literature Critique

The evidence rating scale of Stetler et al[2] was used to evaluate the strength and quality of the research gathered. Of the five articles found to pertain to the research topic, one was a systematic review of randomized controlled trials, thus yielding strong level I evidence. A second study was a randomized controlled trial and a third was a nonrandomized controlled trial design, both yielding level II evidence. The final two studies included a prospective descriptive correlational study and a prospective regional study, both yielding insufficient, level VI evidence. A summary of the evidence found is demonstrated in Table 1. All studies were correlational, meaning that they established the existence of a relationship between the direct and indirect variables, but were unable to specify any single cause of UPH.

Journeaux,[8] in a systematic review of randomized controlled trials, looked at adverse surgical

Table 1. Summary of evidence on perioperative risk factors

	Identification of Study	Method/Level of Evidence	Participants/Sample	Aim of Study	Risk Factors Identified (Intrinsic/Extrinsic)
Article 1	Journeaux.[8] Available from Cumulative Index to Nursing and Allied Health Literature Complete, Ipswich, MA. Accessed November 22, 2015	Systematic review of randomized controlled trials (level IA)	18 Studies selected for review. Inclusion criteria: 2003-2010 English language Research Randomized controlled trials Clinical trials Adults	Aim: to investigate the likelihood of adverse surgical outcomes in patients who experience unplanned perioperative hypothermia	Intrinsic: Preoperative body temperature Extrinsic: Length of surgery
Conclusion: On the basis of this research, ambient room temperature, age, and type of anesthetic cannot be considered risk factors for the purpose of determining practice					
Article 2	Lynch et al[5]	Nonrandomized controlled trial design (level II)	84 Men and women >18 y undergoing laparoscopic cholecystectomy at the Riddle Memorial Hospital in Media, Pennsylvania, from Nov 2007-Sept 2008	Aim: to identify and apply a succinct protocol for the maintenance of normothermia in surgical patients that complies with the Association of Perioperative Nurses Standards of Care	Intrinsic: Neonates Patients who have experienced trauma or burns Older adults Female patients Patients who experience significant fluid shifts Patients with pre-existing conditions Extrinsic: Ambient room temperatures, length of surgery, blood and fluid loss, anxiety, effects of anesthesia, wet skin preps, skin exposure, and use of cold or room temperature fluids for body irrigation
Conclusion: Identification of risk factors will facilitate minimization of risk					
Article 3	Yi et al[9]	A prospective regional study (level VI)	830 Patients who underwent various operations under general anesthesia	Aim: to determine frequency of unplanned intraoperative	Intrinsic: None listed Extrinsic: Major surgery

(Continued)

Table 1. Continued

	Identification of Study	Method/Level of Evidence	Participants/Sample	Aim of Study	Risk Factors Identified (Intrinsic/Extrinsic)
			between Aug and Dec 2013 were randomly selected from 24 hospitals in Beijing through a multistage probability sampling	hypothermia and its concomitant risk factors	Longer duration of anesthesia Infusion of larger amounts (>1,000 mL) of unwarmed intravenous fluid
Conclusion: Variables including major surgery, longer duration of anesthesia, and infusion of greater than 1 L of unwarmed intravenous fluid correlate with increased risk of perioperative hypothermia					
Article 4	de Brito Poveda et al[10]	Prospective, descriptive, correlational study (level IVA)	70 Adult patients undergoing elective surgery at a single facility between August 2006 and June 2007	Aim: to identify factors associated with intraoperative body temperature changes during the perioperative period for elective surgery patients	Intrinsic: Body mass index Need for blood transfusion Extrinsic: Type of anesthesia Duration of anesthesia Mean operating room temperature
Conclusion: Type of anesthesia, duration of anesthesia, body mass index, mean operating room temperature, and the need for blood transfusion were all found to directly associate with the patient's mean body temperature. No statistically significant correlation was found between the patient's mean body temperature and gender, age, or the presence of a chronic condition					
Article 5	Sobczak[11]	Randomized, controlled trial (level IIB)	11 Male patients, physical status score 1 or 2, ages 62-68 undergoing urologic surgery under spinal anesthesia	Aim: to determine whether a reduction in the shivering threshold relates directly to the number of dermatomes blocked by a subarachnoid anesthetic	Intrinsic: Internal redistribution of body heat Heat loss to the environment Inhibition of ventral thermoregulatory control Extrinsic: Extensive spinal blockade
Conclusion: Shivering threshold decreased during epidural and spinal anesthesia. Extensive spinal block impairs central thermoregulatory control more so than a less extensive block					

outcomes secondary to UPH. Articles reviewed focused on adult patients and excluded pediatric patients; pregnant patients; those who experienced planned, therapeutic, induced, or advertent hypothermia; those who received local anesthetics; those who underwent cardiac surgery or cesarean sections; and patients with impaired thermoregulation. Despite common references noted in the literature, Journeaux concluded that sufficient evidence does not exist to consider ambient room temperature, age, or general versus regional anesthesia risk factors of perioperative hypothermia.[8] Journeaux did propose, however, that length of surgery and low preoperative body temperature could correlate with decreased temperatures in the perioperative period and that these patients should receive closer monitoring because of their known risk.[8]

All articles considered in Journeaux's systematic review were subjected to external double-blind peer review and censored for plagiarism using automated software. Furthermore, the 18 articles chosen for review were thoroughly assessed on the grounds of rigor, reliability, and validity. Limitations noted include differences in methodologies of the various studies, thus making side-by-side comparison difficult. Most notably, Journeaux asserts the need for a standard, universal definition of hypothermia, and evidence-based research to identify and prevent risk factors for the development of UPH.[8]

Lynch et al[5] conducted a nonrandomized controlled study aimed at identifying and implementing best practice for maintenance of perioperative normothermia according to the Association of Perioperative Nurses Standards of Care. Adult patients undergoing laparoscopic cholecystectomy were assigned to one of three groups: the first group was warmed throughout the entirety of their perioperative stay via warm blankets, the second group was given prewarmed intravenous fluids throughout their perioperative stay, and the third group was subjected to forced air warming preoperatively, intraoperatively, and postoperatively.[5]

Lynch et al were not able to prove direct causation of UPH by any one specific risk factor.[5] The authors did, however, identify a number of factors that may have contributed to hypothermia including ambient room temperatures, length of surgery, blood and fluid loss, anxiety, the effects of anesthesia, wet skin preps, skin exposure, and the temperature of intravenous fluids.[5] They also proposed that patients at the greatest risk for developing hypothermia include neonates, patients who experience trauma or burns, older adults, female patients, patients who experience dramatic fluid shifts, and patients with preexisting conditions such as peripheral vascular disease, endocrine disorders, pregnancy, or open wounds.[5]

Lynch et al[5] did have some interesting findings despite admitted limitations that include their inability to prove causation, lack of true randomization, and poorly conducted statistical analysis of collected data. They were able to reduce bias by limiting confounding variables, of which the only notable possibilities could be age and sex. They also took care to ensure instrument validity through extensive training for health care providers responsible for temperature measurement and regular tests and calibrations for all thermometers conducted by the Department of Biomedical Engineering. Ultimately, their results could be applied for prevention of UPH in patients older than 18 years undergoing laparoscopic cholecystectomy, but better randomization is needed in further studies.[5]

Yi et al[9] conducted a prospective regional study that aimed to identify the frequency of inadvertent hypothermia and its associated risk factors in a population of Chinese patients. Researchers looked at 830 randomly selected patients through a multistage probability sampling. All patients chosen for participation underwent elective operations under general anesthesia between August 2013 and December 2013 at 24 different medical facilities.[9]

The authors excluded patients with high central fever caused by cerebrovascular disease, cerebral trauma or operations, epilepsy, or acute hydrocephalus, patients with thermoregulation abnormalities such as malignant hyperthermia or neuroleptic malignant syndrome, patients with infectious fevers, patients with a history of hypothyroidism or hyperthyroidism, or patients aged less than 18 years.[9] They then applied multivariate logistic regression analyses to explore the risk

factors for developing hypothermia and presented results as odds ratios with a 95% confidence interval. They found that a major surgery, a long duration of anesthesia, and infusion of 1 L or more of unwarmed intravenous fluid put patients at greater risk for the development of UPH.[9]

One considerable limitation of the Yi et al study is that the frequency of measurement of patients' core temperature in ordinary OR practice may differ from the frequency in this study, which measured tympanic temperatures every 15 minutes throughout the perioperative period. Also given that the study was only conducted in Beijing, it may not accurately extrapolate well to surgical environments outside China.[9] However, as the first study of inadvertent perioperative hypothermia in China, this study does bring to light an important area in which more research is needed.

In 2009, de Brito Poveda et al[10] published the findings of a prospective, descriptive, correlational study specifically aimed to identify factors "associated with intraoperative body temperature changes" in patients undergoing at least 1 hour of anesthesia for elective surgery. A population of 70 adult surgical patients at a charity hospital in Brazil between August 2006 and June 2007 was selected for study. After approval was obtained, multivariate linear regression was used to analyze collected data. Patients with body temperatures greater than 38°C or less than 36°C on entrance to the OR were excluded from the research, and data including OR temperature, humidity, and patient body temperatures at different times were collected.

de Brito Poveda et al[10] concluded that variables such as type of anesthesia, duration of anesthesia, body mass index, mean OR temperature, and the patient's need for blood products directly relate to the patient's core temperature during the perioperative period. Furthermore, they found that no statistically significant correlation (with an accepted level of significance of .05) exists between mean patient body temperature and variables including age ($P = .55$), gender ($P = .07$), or pre-existing chronic conditions ($P = .75$).[10] Limitations identified by the researchers include lack of randomization or blinding, small sample size, the presence of confounding variables, and temperature measurements conducted only every 20 minutes.[10]

Risk factors of perioperative hypothermia related specifically to spinal anesthesia were addressed in a randomized controlled trial conducted in 2014. Sobczak[11] hypothesized that a reduction in the shivering threshold directly relates to the number of dermatomes blocked by a subarachnoid anesthetic.[11] Patients with known ischemic heart disease, cerebrovascular disease, or a contraindication to shivering or infusion of cold fluids were excluded from the population studied.

The study included patients aged 62 to 68 years with an American Society of Anesthesiologists' physical status score of 1 or 2 undergoing spinal anesthesia for urology surgery. Sobczak[11] concluded that three factors contribute to core body hypothermia during regional anesthesia. Internal redistribution of body heat, heat loss to the environment, and inhibition of central thermoregulatory control are created by extensive spinal blockade and decreases the shivering threshold. This may not cause, but does correlate with greater heat loss during the perioperative period.[11] One limitation of this study in particular is the lack of mention of irrigating solution used in the urologic procedures.

In addition to inadequate identification of risk factors, compliance with developed protocols may also be a barrier to maintenance of normothermia in the perioperative period. A 2014 study conducted by Duff et al[12] used retrospective chart auditing of four metropolitan Australian hospitals to identify extremely poor compliance with evidence-based recommendations. Of 400 charts reviewed, they found that 80% of patients did not have a temperature documented intraoperatively. Forty-five percent of intraoperative patients and 77% of postoperative patients did not receive active warming measures when indicated.[12]

Discussion

The reviewed studies offer a wide variety of anecdotal evidence as it pertains to risk factors of UPH. As mentioned previously, because of the impossibility of eliminating all confounding variables, the available literature can at best show correlation between any independent variable and impending hypothermia. At this time, there is no strong evidence to implicate any single independent variable as a causative factor that will increase a patient's risk of UPH.

There were, however, some trends noted in the literature. The most commonly inferred risk factor, which was mentioned in four of the five appraised studies, was length of surgery.[2,5,9,10] Longer duration of surgery may expose the patient for a greater period of time to potentially impaired means of thermoregulation,[11] potentially cold ambient OR temperatures,[5,10] greater volumes of potential intravenous fluids administered,[9] more potential blood and fluid loss,[5] and more potential heat lost to the environment.[11] Along these same lines, Yi et al[9] also proposed that major surgery is another risk factor for UPH. A major surgery will generally require an extended surgery length and greater skin exposure,[5] thus reinforcing the aforementioned risk.

Journeaux[8] identified that a low preoperative body temperature may predispose a patient to inadvertent hypothermia during the perioperative period.[8] Similarly, Lynch et al[5] cited specific patient groups who may be predisposed to low preoperative body temperatures as having increased risk for UPH. Such groups include neonates, patients who have experienced trauma or burns, older adults, female patients, patients who experience significant fluid shifts, and patients with preexisting conditions.[5] Identifying a hypothermic patient and correcting their temperature preoperatively may significantly decrease that patient's exposure to any adverse intraoperative risk secondary to preoperative hypothermia.

Spinal blockade was implicated by Sobczak[11] as a risk factor for the development of hypothermia. As we know, spinal anesthesia can simultaneously inhibit central thermoregulatory control, lead to internal redistribution of body heat, and prevent the body from shivering; all this occurs when the body is actively losing heat to the environment during surgery. The effects of anesthesia, mentioned as a risk factor by Lynch et al[5] and the type of anesthesia, mentioned as a risk factor by de Brito Poveda et al,[10] also support the notion that spinal anesthesia expedites heat loss and thus predisposes a patient to UPH.

Finally, two studies demonstrated insufficient evidence to consider age, whether very young or very old, to be a risk factor for the development of UPH.[2,10] Although patients aged more than 70 years have been commonly cited as an at-risk population in the literature, Journeaux[8] was unable to substantiate this anecdotal evidence. Furthermore, research conducted by de Brito Povedo et al[10] found age to be statistically insignificant (P value = .55) as it relates to patient body temperature. The importance of age as it relates to UPH remains inconclusive.

Several limitations in the compilation of this exhaustive literature review must be acknowledged. Appraised research applied different methodologies for evaluation of risk factors, studied a variety of diverse populations undergoing vastly dissimilar surgical procedures, used a variety of temperature measuring instruments, and recorded distinct study-specific outcome measures. Ultimately most limiting, no conclusive or strong evidence was presented by any of the literature reviewed, leaving only circumstantial evidence regarding correlation. Future studies should strive to eliminate as many confounding variables as possible, manipulate only one variable, and draw conclusions about direct causation or lack of causation of UPH.

Conclusions

A number of barriers exist to the maintenance of perioperative normothermia. Most importantly, there is a severe shortage of evidence-based data to implicate any single risk factor for the development of UPH. However, identification of true risk factors may not be the only barrier to prevention of hypothermia. Observance of proper monitoring standards and compliance with developed protocols may also hinder progress.[11] Identifying at-risk patients and eliminating that risk is the first step to combat adverse outcomes of hypothermia, but compliance in the implementation of temperature management protocols being developed will be a crucial component in enhancing patient safety.

At this time, only anecdotal evidence is available to guide our efforts in the maintenance of perioperative normothermia. There is currently no strong evidence to implicate risk factors that do or do not cause a patient to develop UPH. Fortunately, the Cochrane collaboration is in the process of conducting three systematic literature reviews related to UPH prevention.[13] Hopefully this will yield better guidelines for determining which

patients pose the greatest risk for UPH and intervening to prevent any adverse outcomes before they materialize.

Vast amounts of evidence-based information exist regarding the physiology of thermoregulation, types of heat loss, and adverse effects of hypothermia. Health care professionals understand why hypothermia happens, how it happens, and why it must be prevented; but that alone is not enough. The remarkable lack of research implicating any risk factors as causative agents in the development of UPH impedes our ability to intervene. We understand that low perioperative temperatures increase a patient's risk for infection and undesired coagulation, but how should we prevent this?

The ability of health care providers is to identify risk factors and implement interventions is crucial in the prevention of UPH. However, vigilance in the perioperative period can enhance patient safety when we know the factors to observe. More research is needed to identify risk factors of UPH and effectively maintain normothermia throughout the perioperative period.

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