A Review of the Evidence: Prewarming Adults Prior to General Anesthesia in the Prevention of Unplanned Perioperative Hypothermia

Paige Wrigley

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Tonia Kennedy, RN, CCRN, M.S.N., Ed.D.
Thesis Chair

_____
Kimberly Brown, RN, NEA-BC, DNP
Committee Member

_____
David Schweitzer, Ph.D.
Committee Member

_____
James H. Nutter, D.A.
Honors Director

_____
Date

Abstract

Unplanned perioperative hypothermia (UPH), a common event in the surgical setting, is associated with many adverse patient outcomes. In current perioperative practice, patient core temperature is monitored and active warming interventions are implemented during the intraoperative and postoperative phases in response to UPH. The literature suggests preoperative warming of patients as a proactive measure may be more effective in the prevention of UPH. In the form of an integrative review, this thesis seeks to address the research question: For adult patients undergoing general anesthesia, how does preoperative warming compared to no preoperative warming affect UPH incidence? A database search yields ten studies for inclusion and study findings are synthesized and summarized. The conclusion is drawn there is sufficient evidence to support preoperative warming as an effective measure to decrease UPH incidence and should be considered for implementation in clinical practice as the benefits outweigh the risks.

A Review of the Evidence: Prewarming Adults Prior to General Anesthesia in the Prevention of Unplanned Perioperative Hypothermia

General anesthesia is a medically induced state that makes one unconscious and unable to feel pain during medical procedures; it is most commonly produced by a combination of intravenous drugs and inhaled anesthetics (Mayo, 2013). While general anesthesia is an amazing phenomenon that has immensely benefitted healthcare to allow for life-saving surgical operations that would be otherwise impossible, it also poses a risk for serious complications and even death. Perioperative healthcare providers must therefore always be seeking ways to improve practice and reduce potential risks to patients. One potential risk to a patient under general anesthesia is a perioperative decrease in core body temperature leading to unplanned perioperative hypothermia (UPH).

While there is no universally accepted definition for perioperative hypothermia or normothermic core body temperature, according to the American Society of PeriAnesthesia Nurses (ASPAN), a temperature <36°C (96.8°F) is used to define perioperative hypothermia (2010). According to the United States National Library of Medicine, a temperature within 36.1°C-37.2°C (97-99°F) is used to designate a normothermic core body temperature (Vorvick, 2013). UPH occurs when a patient's core body temperature becomes hypothermic at any moment in the perioperative period. Even mild hypothermia, a core body temperature of 34-36°C (93.2-96.8°F), at any time throughout the perioperative period presents a risk for adverse outcomes to the patient (Hooper et al., 2010).

Without aggressive normothermia management, hypothermia imminently accompanies general anesthesia administration and can be divided into three phases. During phase I, the first hour of anesthesia, general anesthetic induced vasodilation causes a core-to-peripheral redistribution of body heat. This is followed by phase II, several hours of heat loss exceeding heat production and a linear reduction in core body temperature. During phase III, the plateau phase, hypothermia stabilizes due to the body's core temperature deviating far enough below the inter-threshold range to activate thermoregulatory vasoconstriction (Matsukawa et al., 1995).

According to Díaz and Becker (2010), under normal conditions, the temperature of deep body tissues, referred to as core temperature, remains relatively constant at 36-37°C (98.0-98.6°F) despite one's environment. Even under extreme environmental temperature conditions ranging from as low as 12.7°C (55°F) to as high as 54.4°C (130°F), core temperature can be maintained between 36.1- 37.7°C (97-100°F) in a healthy individual. This is due to the body's incredible thermoregulatory system, consisting of afferent sensing, hypothalamic central control, and efferent responses. As the skin, core tissues, spinal cord, and brain continually relay temperature input to the hypothalamus, these temperature inputs are integrated and compared to set-point temperatures that trigger appropriate thermoregulatory responses. The responses are normally initiated by deviations as small as 0.1°C from normal core temperature of 37°C (Díaz & Becker, 2010).

Thus, when core temperature becomes greater than 37.1°C (98.8°F), sweating is induced followed by vasodilation. When core temperature becomes less than 36.9°C (98.4°F), vasoconstriction is induced followed by shivering. Following, the difference

between core body temperatures inducing the sweating and vasodilation response versus the vasoconstriction and shivering response is only 0.2°C, defined as the inter-threshold range during which the body does not initiate thermoregulatory effects. Most general anesthetics depress hypothalamic responses, widening this inter-threshold range to as much as 4°C. As patients undergoing surgical procedures are already predisposed to heat loss by skin exposure to the cold operating room (OR) environment, evaporation of surgical skin preparation, administration of cold intravenous fluids and blood products, and use of cold, dry anesthetic gases, this widening of the inter-threshold range further exacerbates hypothermia development as patient thermoregulatory control and protective response mechanisms are weakened (Díaz & Becker, 2010; Roberson, Dieckmann, Rodriguez, & Austin, 2013).

Additionally, with general anesthesia induction and resulting vasodilation throughout the body, rapid redistribution of body heat from the core to the peripheral tissues is observed as heat flows down the temperature gradient from the warmer core to the cooler periphery. This phenomenon is known as redistribution hypothermia (Matsukawa et al., 1995). Under normal conditions, once the hypothalamus had detected such a change in core body temperature, vasoconstriction followed by shivering would be induced to maintain core body temperature at 37°C (Díaz & Becker, 2010). However, as anesthetics blunt this thermoregulatory response, a rapid drop in core temperature is often observed within the first hour of general anesthesia administration (Matsukawa et al., 1995). Once the change in core body temperature becomes great enough for the hypothalamus to sense within the inter-threshold range, thermoregulatory mechanisms will reappear in attempt to raise the core body temperature (Díaz & Becker, 2010).

However, this return of thermoregulation often may not occur until a patient has already reached a moderate to severe level of hypothermia, putting the patient as risk to the detrimental effects of hypothermia during that time. The body's natural thermoregulation mechanisms may not be sufficient at that point to warm the patient to normothermic levels within a reasonable timeframe. Even clinical interventions such as active warming of the patient with forced-air warming devices intraoperatively or postoperatively may not be sufficient to treat redistribution hypothermia because heat applied to the skin with forced-air warming methods requires a considerable amount of time to reach the core compartment (Hooper et al., 2010).

Although intraoperative and postoperative warming interventions have attenuated for UPH to a degree and are utilized as the current standards of care in the maintenance of perioperative normothermia, hypothermia remains a significant clinical problem (De Brito Proveda, Clark, & Galvão, 2013; Fossum, Hays, & Henson, 2001; Roberson et al., 2013). De Brito Proveda et al. (2013) and Roberson et al. (2013) have recently published systematic reviews of the literature in regards to studies exploring the efficacy of preoperative warming interventions in the prevention of UPH. Both reviews conclude there is evidence to support preoperative warming in addition to intraoperative warming methods may prove successful in reducing perioperative hypothermia incidence. According to Hooper et al. (2010), preoperative warming, or prewarming, is defined as, "warming of peripheral tissues or surface skin before induction of anesthesia" (p. 352).

Prewarming is believed to reduce hypothermia by provoking vasodilation and reducing the core-to-peripheral temperature gradient by increasing total body heat content (Hooper et al., 2010). By supplying additional heat to the patient's peripheral

compartments and allowing the body to adjust to vasodilation while normal thermoregulation mechanisms are still in place, once general anesthesia is induced, the normally observed core to peripheral heat redistribution due to rapidly induced anesthetic vasodilation is diminished, and UPH incidence is reduced. Thus, prewarming could prove especially vital in reducing UPH during phase I, the first hour of anesthesia, where general anesthetic induced vasodilation causes a core-to-peripheral redistribution of body heat (Díaz & Becker, 2010).

UPH is associated with many detrimental physiologic alterations in patients including decreased metabolic rate, decreased cardiac output, impaired clotting function, metabolic acidosis, peripheral vasoconstriction, decreased tissue perfusion, decreased resistance to infection, alterations in serum potassium levels, and increased shivering with resultant increased oxygen demand of up to 400-500% (Fettes, Mulvaine, & Van Doren, 2013; Roberson et al., 2013). As a result of these physiologic alterations, UPH may cause an increased duration of action of anesthetic medications, increased infection and pressure ulcer incidence, tissue ischemia (especially myocardial), and increased risk of morbidity often attributed to adverse cardiac events. UPH also contributes to an increased length of post-anesthesia care unit (PACU) and hospital stay, poor patient perception of care, and excess hospital costs (Adriani & Moriber, 2013). It is estimated that avoidance of intraoperative hypothermia by normothermia maintenance can reduce hospital costs for a patient by $2,500 to $7,000 (Mahoney & Odom, 1999).

Of all perioperative thermal disturbances, hypothermia is most commonly observed, and the reported incidence rate varies from 6-90% of surgical procedures (Monzón et al., 2013). One recent source suggests as many as 50-70% of all surgical

patients experience UPH (Roberson et al., 2013). Thus, research directed towards evidence-based practice for the optimal maintenance of normothermia and prevention of UPH is warranted. Studies demonstrating the adverse effects of UPH have been appearing in the literature since the late 1990s. One such classic clinical trial studying perioperative maintenance of normothermia concluded with a likely conservative estimate that hypothermic patients were three times as likely to experience unfavorable myocardial events as compared to non-hypothermic patients (Frank et al., 1997). Another benchmark study found a profound statistically significant difference (p= 0.001) in wound infection incidence between prewarmed and non-prewarmed groups of patients undergoing clean surgeries with 14% of non-prewarmed patients (exhibiting more cases of UPH than the prewarmed group) developing an infection as compared to only 5% of prewarmed patients (Melling, Ali, Scott, & Leaper, 2001).

Other studies have suggested hypothermia may directly impair neutrophil function and trigger subcutaneous vasoconstriction, resulting in tissue hypoxia and owing to the decreased immune response causing an increased incidence of surgical wound infection (Beilin, et al., 1998; Sessler, 2008). Despite these harmful effects of unplanned hypothermia in the perioperative setting, it should be noted that hypothermia may be prescribed therapeutically at times. For example, the American Heart Association currently recommends use of therapeutic hypothermia to decrease the oxygen demands of patients after witnessed cardiac arrest and for patients in which posthypoxic injuries are likely (Polderman, 2015). Whether hypothermia is induced therapeutically or occurs inadvertently in the perioperative setting, the literature clearly documents the increased

risk of adverse effects correlated with hypothermia (Frank et al., 1997; Kurz, Sessler, & Lenhardt, 1996; Melling et al., 2001; Vaughan, Vaughan, & Cork, 1981).

In recognition of the prevalent clinical problem of perioperative hypothermia and other thermoregulation issues, clinical guidelines and recommendations have been published by various healthcare organizations advocating for perioperative normothermia maintenance (Hooper et al., 2010; "Inadvertent perioperative hypothermia," 2008). One such organization, ASPAN, recruited a team of multidisciplinary, multispecialty experts in the field including representatives from ASPAN, the American Association of Nurse Anesthetists (AANA), the American Society of Anesthesiologists (ASA), and the Association of PeriOperative Nurses (AORN) to produce evidence-based clinical practice guidelines concerning this issue. In 2010, the second edition of *ASPAN'S Evidence-Based Clinical Practice Guideline for the Promotion of Perioperative Normothermia* was published with the specific aim of "developing consensus-based, multimodal practice recommendations gleaned from and supported by the strongest levels and quality of evidence available" ("Normothermia," 2015).

As this thesis seeks to evaluate how preoperative warming of adults undergoing general anesthesia affects UPH occurrence, the current clinical standards of care to promote perioperative normothermia will be discussed and how preoperative warming fits into these standards. The 2010 ASPAN guidelines recommend patient assessment, interventions, and outcomes to be achieved during each of the preoperative, intraoperative, and postoperative phases of care. The preoperative assessment should include an assessment of risk factors for UPH, a patient temperature on admission, determination of patient thermal comfort level, assessment for shivering, piloerection,

and/or cold extremities, and documentation and communication of risk factor assessment findings to all members of the surgical/anesthesia team. Although no strong evidence exists that certain risk factors are necessarily correlated with UPH, there is weak evidence that extremes of age, systolic blood pressure less than 140 mm Hg, female gender, and level of spinal block are all risk factors correlated to patient development of UPH (Hooper et al., 2010).

In regards to core temperature measurement, the guidelines state the most accurate sites as the pulmonary artery, distal esophagus, nasopharynx, and tympanic membrane (via a thermistor); however, obtaining these core temperatures measurements are usually clinically impractical and/or infeasible. Therefore, *near* core temperature measurements must be relied upon from sites such as oral, bladder, rectal, axillary, temporal artery, or tympanic membrane (via infrared sensor). The guidelines proceed to state there is strong evidence to suggest the most accurate near core temperature measurement site is oral, that the same route of temperature measurement should be used throughout the perianesthesia period for consistency and comparison purposes, and that caution should be taken in interpreting extreme value measurements (< 35°C or >39°C) from any near core site. There is weak evidence to suggest temporal artery measurements approximate core temperature accurately at normothermic temperatures but not at extremes outside of normothermia. There is also weak evidence to suggest an infrared sensor at the tympanic membrane does not provide accurate temperature measurements during the perianesthesia period (Hooper et al., 2010).

Preoperative interventions should include ambient room temperature maintenance of 24°C or greater, passive thermal care measures for all patients (includes

the application of warmed cotton blankets, reflective blankets, socks, and head covering, as well as limiting skin exposure to lower ambient room temperature), active warming measures for hypothermic patients (includes the application of a forced-air convection warming system as well as a circulating-water mattress, resistive heating blankets, radiant warmers, negative-pressure warming systems, and warmed humidified inspired oxygen), and consideration of preoperative warming for 30 minutes to reduce the risk of intra/postoperative hypothermia. Expected preoperative outcomes should include patient expression of thermal comfort, non-emergent patients being normothermic prior to transfer to the OR or procedure area, and emergent patients being warmed as soon as clinically appropriate (Hooper et al., 2010).

In regards to the intraoperative phase, the following interventions should be implemented as a bare minimum standard for all patients: limit skin exposure to lower ambient environmental temperatures, maintain ambient room temperature from 20-25°C based on AORN and architectural recommendations, and initiate passive warming measures (cotton blankets, surgical drapes, plastic sheeting and reflective composites also known as space blankets). For patients who are preoperatively hypothermic, at risk for hypothermia, at increased risk for suffering hypothermia complications, or undergoing a procedure with an anticipated anesthesia time greater than 30 minutes, forced-air warming measures should be initiated. There is evidence alternative active-warming measures may maintain normothermia when used alone or in combination with forced-air warming methods including: warmed IV fluids, warmed irrigation fluids, circulating water garments, circulating water mattresses, radiant heat, gel pad (Arctic Sun) surface warming, and resistive heating. The expected outcome for the intraoperative stage is

patient normothermia upon discharge from the OR or procedure area. The postoperative phase of care involves further core temperature assessment and monitoring, interventions as needed to maintain normothermia, and an expected outcome of normothermia and patient verbalization of thermal comfort (Hooper et al., 2010).

Purpose

The conceptual model providing purpose for the integrative review is the Iowa Model, a framework often used in nursing research to drive evidence-based practice. In following the Iowa Model, the first step is identification of a relevant clinical problem. Perioperative healthcare providers daily face the clinical problem of attenuating for potential UPH and associated adverse outcomes in their patients; this serves as the clinical problem to be addressed in the review. The next step of the Iowa Model calls for the clinical problem to be translated into a research question using the PICO format. Within the acronym PICO, each letter represents a factor to posing a forceful clinical research question: patient population, intervention, comparison, and outcome. This clarification of the question focuses the review to most effectively address the topic under consideration. Using the PICO format, the following clinical question can be devised: For adult patients undergoing general anesthesia, how does the implementation of preoperative warming compared to no preoperative warming affect the incidence of UPH?

The next step of the Iowa Model calls for a literature review of relevant sources pertaining to the PICO question and should determine what is known and unknown in the literature concerning the topic. Although ASPAN's current guidelines in addition to other healthcare organizations' guidelines suggest consideration of preoperative warming for

30 minutes to reduce the risk of intra/postoperative hypothermia, there are still questions concerning prewarming's efficacy in regards to best practice that warrant further research. Following, the primary purpose of this integrative review is the identification of what is known and unknown (i.e. consistencies and gaps) in the literature regarding how preoperative warming affects the incidence of UPH in adult patients undergoing general anesthesia. Following, a secondary purpose of this review seeks to determine how this issue can best be managed and resolved in clinical practice based upon the evidence found in the literature.

Regarding the final steps of the Iowa Model once the literature review is complete, gaps and inconsistencies identified in the literature indicate a need for further research conduction and serves as a place for researchers to begin new studies. On the other hand, sufficient evidence and consistencies in the literature supporting a change in practice warrant quality improvement projects leading to modification and confirmation of policies, procedures, and protocols and an ultimate evidence-based change in practice (Boswell & Cannon, 2014). Thus, this integrative review seeks to provide a background and context for further research to be conducted while potentially drawing new implications for practice to ultimately produce better patient outcomes.

Method

The first step of the integrative review entails identification of a relevant clinical problem and formulation of the problem into the PICO question format. This is followed by a systematic search of the literature using specific databases, key words and subject headings, and inclusion-exclusion criteria to select articles to be included in the review. Once pertinent sources for the review are selected, data is systematically extracted from

each source concerning the study purpose, sample, method, results, limitations, gaps, and conclusion. Each study is rigorously evaluated and appraisal of the evidence is performed using ©The Johns Hopkins University Nursing Evidence-Based Practice Appendix E: Research Evidence Appraisal Tool to determine each study's strength of the evidence and quality rating to determine the study's trustworthiness when considering its purported findings. Each study's purported results and conclusions are displayed in table format along with its appraisal ratings and the reviewer's critique and commentary. As each source is evaluated and the information compared and synthesized across the studies, limitations and gaps appearing throughout the studies are identified, and a discussion is given and a conclusion drawn as to what is known in the literature regarding how preoperative warming of adult patients undergoing general anesthesia affects the incidence of UPH.

Inclusion and Exclusion Criteria

Inclusion criteria include peer-reviewed quantitative primary studies published within the past 5 years (August 2010-August 2015) with an adult population (18 years of age or greater) undergoing general anesthesia that examines the effects of a preoperative warming intervention on perioperative hypothermia outcomes. According to Hooper et al. (2010) and for the purpose of this integrative review, prewarming will be defined as, "warming of peripheral tissues or surface skin before induction of anesthesia." Exclusion criteria include articles in a language other than English, and studies examining populations such as pediatrics, geriatrics, obstetrics, or special consideration populations in which thermoregulatory mechanisms could be impaired. These special consideration

populations include but are not limited to patients with thyroid disease, autonomic dysfunction, peripheral vascular disease, or active infection.

Search Strategy

The following databases are utilized: Cumulative Index to Nursing & Allied Health (CINAHL), Medical Literature Analysis and Retrieval System Online (MEDLINE), Proquest Nursing & Allied Health Source, Cochrane Library, Journals@Ovid, Health Source: Nursing/Academic Edition, and ScienceDirect College Edition. Within each database, advanced search techniques are used that selectively retrieve only peer-reviewed journal articles published from August 2010-August 2015 using controlled subject headings and non-controlled key word searches. The following search terms are used in various combinations: warming, prewarming, preoperative warming, forced-air warming, active warming, hypothermia, perioperative hypothermia, and general anesthesia. Once a relevant article to the topic is identified, the reference list is searched for further potential sources. A total of ten articles meet the inclusion and exclusion criteria and are used for the integrative review.

Data Collection

Data collection consists of extracting study characteristics of each article into an organized table for the reviewer's purpose of systematic organization and comparison and contrasting of the studies including: title, author, journal publication, study purpose, sample size and selection, sample demographics, geographic location, study design, instruments, data collection, data analysis, results, statistical significance, limitations, gaps, and conclusion. A table is created and included in the results section to more

succinctly display these collected data concerning each study's major characteristics. See Table 1.

Data Analysis

Data is analyzed in the form of integrative review. According to Boswell & Cannon (2014), the integrative review summarizes all quantitative evidence found through the literature search that is correlated to an identifiable research or clinical issue, employing a rigorous format to ensure completeness of assessment and draws conclusions from the summary concerning the studies examined (Boswell & Cannon, 2014). To perform consistent appraisal of the quantitative evidence for each study, the review utilizes ©The Johns Hopkins University Nursing Evidence-Based Practice Appendix E: Research Evidence Appraisal Tool. This tool is a validated instrument for research evidence appraisal and is used with the permission of ©The Johns Hopkins University. In appraisal of each study, based upon the study design, the strength of the evidence is graded as level one, two or three. Based upon the quality of the scientific evidence presented in the study, the quality rating is graded as high, good, or low. See Table 2. In consideration of each study's purported results and conclusions and its appraisal rating, a critique regarding the significance of the findings is presented. See Table 3.

Results

Table 1 presents a summary of study characteristics. Each study utilizes varying definitions for the age range of an adult, but an adult can be defined as at least 18 years of age across all the studies.

Table 1. *Study Characteristics* (ASA=American Society of Anesthesiologists; BMI= body mass index; OR= operating room; PACU= post-anesthesia care unit; SD= standard

deviation)

Study Author; Journal; Setting; Design	Intended Study Purpose	Sample Size (n) & Demographics	Surgery Type & Duration	Preoperative Warming Device; Duration; Temperature & Intraoperative Warming for Both Groups	OR Ambient Temperature	Core Temperature Measurement Time Intervals & Instruments
Adriani & Moriber (2013) *AANA Journal* Bridgeport Hospital, Connecticut Quasi-experimental	To investigate if preoperative warming with a patient adjustable warming system combined with intraoperative warming is more effective in the prevention of hypothermia compared with traditional intraoperative warming alone with the Bair Hugger blanket	n=60 Female adults 18-85 years (mean age prewarmed: 49 years non-prewarmed: 47 years) undergoing general anesthesia with an endotracheal tube, ASA class I-III	Laparoscopic and open gynecologic surgeries: total abdominal hysterectomy, ovarian cystectomy, oophorectomy, vaginal hysterectomy, myomectomy Duration not listed	Pre-warmed group: Forced-air warming gown (Bair Paws); at least 30 minutes (mean: 51 minutes); temperature controlled by patient with handheld device Both groups: forced-air warming blanket (Bair Hugger) initiated at anesthesia provider discretion, warmed IV fluids for all patients	Not controlled for	Intervals not clearly described: Preoperative baseline temperature prior to prewarming, first temperature reading in the OR, and PACU temperature Preoperative and Postoperative: Oral SureTemp Plus electronic thermometer (Welch Allyn) Intraoperative: Esophageal via Level 1 acoustascope esophageal stethoscope (Smiths Medical)
Erdling & Johansson (2015) *AANA Journal* General hospital in southern Sweden Experimental	To determine the intraoperative temperatures with 2 different measurement techniques (esophagus versus nasopharynx), directly comparing these 2 measurement techniques in the same patient, this issue was evaluated in 2 groups, Group A with prewarming and Group B without prewarming	n= 43 Adults (mean age 70 years) undergoing general anesthesia combined with regional analgesia for an anticipated anesthesia time of at least 210 minutes, ASA class I-II	Elective open colorectal surgery Duration not listed, but an anticipated anesthesia time of at least 210 minutes required as inclusion criteria	Pre-warmed group: Forced-air warming device (Warm Touch, Nellcor, or Gaymar, Smiths Medical) covering both arms, head, and thorax; 42 ± 10 (mean ± SD in minutes); 43°C Both groups: Layer of quilted cotton on the legs only and covered with the surgical drape, forced-air warming device (Warm Touch, Nellcor, or Gaymar, Smiths Medical) covering both arms, head, and thorax; IV fluids warmed to 39°C	No mention whether controlled for, but recorded temperatures listed: At anesthesia induction: 21.9 ± 0.8 °C (mean ± SD) for both groups At 210 minutes intraoperatively: Prewarmed group: 22.1 ± 0.6 °C (mean ± SD) Non-prewarmed group: 22.4 ± 0.7 °C (mean ± SD)	Temperature monitored continuously and recorded at following intervals to reflect 3 phases of hypothermia: Prior to anesthesia induction, anesthesia start, surgery start, post 30, 90, 120, 150, 210, 270, 330, 390, 450, & 510 minutes surgery start Esophageal and nasopharyngeal Level 1 disposable general purpose temperature probes (Smiths Medical)
Fettes et al. (2013) *AORN*	To compare the temperature of patients undergoing	n=128 English speaking	Exploratory laparotomy, colorectal surgery, total	Prewarmed group: Forced-air warming blanket; approximately 60	Not controlled for	Intervals not clearly described, narrative states time intervals as: Pre-, intra-, and post-

Journal Independently owned Magnet status community hospital, Marshall, Michigan Experimental	surgery who did not receive forced-air warming before induction of anesthesia with patients who did receive forced-air warming before anesthesia	adults (mean age 59 years) undergoing general anesthesia, ASA class I-III, admission temperature 36.6-37.5°C	joint replacements (hip and knee), spinal and chest procedures, total abdominal hysterectomy, robotic-assisted nephrectomy, prostatectomy, cystectomy Duration not listed	minutes; 37.8 °C Both groups: Warm cotton blankets, forced-air warming blanket, warmed IV and irrigation fluids		operative; table only lists temperature results for the following time intervals: Admission to outpatient department, exiting preoperative area, admission to PACU Temporal artery-scanning thermometer
Hooven (2011) *Journal of PeriAnesthesia Nursing* St. Mary Medical Center, Langhorne, PA Quasi-experimental	To determine whether the patients who received preprocedure warming maintained normothermia throughout the perioperative period, indicated by a normothermic tympanic temperature reading (96.8-100.4°F) upon arrival to the PACU	n=149 Adults (mean age 64 years) undergoing general anesthesia, preoperative temperature of less than or equal to 38°C	Colorectal surgeries: hemicolectomy, laparoscopic colon resection, transverse colon resection, sigmoid colon resection, and ostomy Mean duration in OR: Prewarmed group: 158 minutes Non-prewarmed group: 180 minutes	Prewarmed group: Beginning March 2008, all colorectal patients received prewarming with forced air-warming gown (Bair Paws); 60 minutes; temperature of warming device not listed During 2007, all colorectal patients received standard perioperative care which did not include prewarming (specific perioperative standards of care not listed)	Controlled for to remain 20.0-22.2 °C and remained within this range throughout the two year study period	Intervals: Preoperatively prior to prewarming intervention, and first recorded temperature upon arrival to the PACU Genius 2 infrared tympanic thermometer (Covidien)
Horn et al. (2012) *Anesthesia* Not mentioned Experimental	To evaluate whether shorter periods of 10, 20 or 30 min of forced-air prewarming compared with passive insulation may be long enough to reduce the incidence of postoperative hypothermia and shivering	n=200 Adults (mean ages of 4 groups: 49, 55, 52, 54 years) undergoing general anesthesia with expected duration > 30 but < 90 minutes, ASA class I-II	Elective laparoscopic cholecystectomy, inguinal hernia repair, breast surgery; minor orthopedic surgery, ENT surgery Mean surgery duration: Prewarmed 10 minutes group: 60 minutes Prewarmed 20 minutes group: 60 minutes Prewarmed 30 minutes group: 65 minutes Non-prewarmed group: 65	Prewarmed groups: Forced-air warming blanket (Snuggle Warm Upper Body Blanket) covered by cotton blanket, connected to Level 1 Equator warmer (Smiths Medical); 10, 20, or 30 minutes by randomization; 44 °C (if patient reported feeling overheated warmer lowered to 40 °C) All groups: Cotton blankets, forced-air warming blanket (Snuggle Warm Upper Body Blanket) initiated if core temperature decreased below 36 °C, all fluids warmed to 39 °C	Controlled for to remain near 23 °C	Intervals: Pre-op care unit arrival, 10, 20, 30 minutes post pre-op care unit arrival, OR arrival, 15, 30, 45, 60, 75, 90 minutes post OR arrival, PACU arrival, 15, 30, 45, 60 minutes post PACU arrival Tympanic membrane temperature sensor (Smiths Medical)

			minutes			
Kramer (2013) *Journal of PeriAnesthesia Nurisng* Large academic medical center Quasi-experimental	To determine if prewarming would help maintain perioperative normothermia in women undergoing breast reconstruction surgery with a transverse rectus abdominis myocutaneous (TRAM) free flap compared to women who were not prewarmed	n= 24 Adult women undergoing general anesthesia and TRAM breast reconstruction	Elective breast reconstruction surgery with a transverse rectus abdominis myocutaneous (TRAM) free flap Duration not listed	Prewarmed group: Forced-air warming gown; minimum of 30 minutes; temperature of warming device not listed Data was compared to 12 patients chosen at random from the previous 12 months who underwent TRAM breast reconstruction and received standard perioperative care which did not include prewarming (specific perioperative standards of care not listed)	Not controlled for	Intervals not clearly described: Prior to and after prewarming intervention in the preoperative area, temperature monitored continuously in the OR, temperature monitored in the PACU Preoperative and Postoperative: oral thermometer Intraoperative: esophageal thermometer
Nicholson (2013) *AORN Journal* Accredited & licensed tertiary hospital Experimental	To determine whether prewarming with a forced air-warming gown versus no prewarming would result in differences between the two groups regarding: 1) Preoperative temperatures 2)Intraoperative temperatures 3)Postoperative temperatures 4) Incidence of UPH	n=66 Adults (narrative states typical age 59 years) undergoing general anesthesia in a same day admission colorectal surgery, ASA class I-IV, preoperative temperature of 37°C or less	Elective laparoscopic or nonlaparoscopic surgical colorectal procedure Duration not listed	Pre-warmed group: Forced-air warming gown; at least 30 minutes, 75 ± 56 (mean ± SD in minutes); temperature of warming device not listed Both groups: Majority of participants received forced-air warming of upper body, warmed irrigation fluids, warmed humidified gases, and warmed IV fluids	No mention whether controlled for, but mean recorded temperatures listed: Prewarmed group: 19.9°C Non-prewarmed group: 19.8°C	Intervals: Preoperative (for prewarmed group, temperature recorded after atleast 30 minutes of prewarming), intraoperative (first temperature recorded after intubation), postoperative (temperature recorded within 15 minutes of arrival in PACU) Preoperative and Postoperative: portable electronic thermistor oral thermometer Intraoperative: oral thermistor, nasal, esophageal, or rectal temperature probe or temperature-sensing urinary catheter at the discretion of anesthesia provider
Perl et al. (2014) *Minerva Anestesiologica* Two university hospitals and one	To determine the efficacy of a novel prewarming method that could attain higher core temperatures at end of surgery and reduce incidence of	n= 68 Adults 18-70 years (mean ages of 3 groups: 52, 45, 43 years) undergoing general anesthesia	Elective abdominal, chest, lower limb, upper limb, head and neck procedures Mean anesthesia duration:	Active prewarmed group: Mistral-Air Premium warming Suit and forced-air warming with (Mistral-Air warming unit); 30-60 minutes; temperature of warming device not listed	No mention whether controlled for, but mean recorded temperatures listed: Non-prewarme	Intervals: Preoperatively on the ward, prior to pre- warming, prior to anesthesia induction, 15, 30, 45, 60, 75, 90, 105, 120, 135 minutes post anesthesia induction, end of surgery, PACU arrival, 10, 20, 30, 40, 50, 60 minutes post PACU

general hospital Experimental	perioperative hypothermia during general anesthesia	for an anticipated anesthesia time of 30-120 minutes, ASA class I-III, BMI of 20-30 kg/m2, preoperative temperature of 35-38 °C	Passive prewarmed group: 97 minutes Active prewarmed group: 99 minutes Non-prewarmed group: 81 minutes	Passive prewarmed group: Mistral-Air Premium warming Suit (The 37 Company) All groups: Actively warmed immediately after induction of anesthesia and throughout surgery duration using forced-air warming upper body blanket or lower body blanket (Mistral Air). IV fluids warmed to 37 °C	d group: 20.5 ± 1.3°C (mean ± SD) Passive prewarmed group: 20.5 ± 1.1°C (mean ± SD): Active prewarmed group: 20.6 ± 0.9°C (mean ± SD)	arrival. Preoperative and Postoperative: Oral electronic thermometer (Geratherm Medical) Intraoperative: Esophageal temperature probe inserted 30 to 35 cm into the distal esophagus (Temprecise, Arizant Healthcare)
Rowley (2014) *Clinical Nursing Research* Unspecified hospital Quasi-experimental	To investigate how the use of a preoperative forced-air warmer and adjustment of surgical room ambient temperature may contribute to core body temperature changes	n=220 Adults (mean age 66 years) undergoing general anesthesia for surgical procedures of a minimum of 60 minutes in duration. BMI <30 kg/m^2, preoperative temperature of 38°C or less	Elective major (open) abdominal procedures, total hip replacements, total knee replacements, lumbar spinal fusion surgery Duration not listed, but an anticipated anesthesia time of at least 60 minutes required as inclusion criteria	Prewarmed groups: Forced-air warming blanket; approximately 20-30 minutes; 43°C All groups: Room temperature flannel bath blanket after changing into hospital gown, forced-air warming blanket, warmed flannel bath blanket before transfer to PACU	Controlled for in 2 groups: 21.1°C prior to patient OR arrival, readjusted to staff comfort, then set back to 21.1°C prior to surgery end Not controlled for in other 2 groups	Intervals: Immediately following consent in the preoperative unit, entrance to OR, time of incision, end of surgery, PACU admission, PACU discharge Medical grade temporal lobe infrared probe thermometer
Shin et al. (2015) *BMC Anesthesiology* Kang Dong Sacred Heart Hospital (Seoul, South Korea) Experimental	To evaluate the efficacy of skin surface warming using a forced-air warming blanket for 30 minutes prior to induction of anesthesia to prevent the decrease in core temperature that occurs during endovascular coiling of cerebral aneurysms and reduce the incidence of hypothermia	n= 72 Adults (mean age prewarmed: 56 years non-prewarmed: 60 years) undergoing general anesthesia. BMI <35 kg/m^2, preoperative temperature of less than or equal to 37.2°C	Elective or emergency endovascular coiling to treat cerebral aneurysm Mean anesthesia duration: Prewarmed group: 137 minutes Non-prewarmed group: 139 minutes	Prewarmed group: Forced-air warming full body blanket (Bair Hugger) covering entire body except head and neck connected to warm air-blower; 30 minutes and maintained until anesthesia induction; 38°C Both groups: Forced-air warming upper body blanket (Bair Hugger). If core temperature decreased below 35.5°C, air-blower initiated at 43°C	Controlled for to remain 19- 21°C Non-prewarmed group: 19.8 ± 0.6 (mean ± SD) Prewarmed group: 20.0 ± 0.5 (mean ± SD)	Intervals: Pre-induction, immediately after intubation, 20, 40, 60, 80, 100, 120 minutes post-intubation Preoperative: Infrared tympanic thermometer (Instant Thermometer HM3) Intraoperative: Esophageal temperature probe (DeRoyal Esophageal Stethoscope)

Table 2 presents the quality appraisal results for each study according to ©The Johns Hopkins University Nursing Evidence-Based Practice Appendix E: Research Evidence Appraisal Tool. In regards to discussion of instrument validity, the instrument refers to the device used to measure core-temperature, which were varying types of thermometers throughout the studies. An adequate discussion of instrument validity entails the validity or extent to which the thermometer measures core body temperature accurately in degrees. In regards to instrument reliability, or extent to which the core-temperature measurement device consistently performs as it is designed to perform, Cronbach's alpha analysis is non-applicable. Instrument reliability can be determined by ensuring thermometer calibration and testing to confirm function, safety, and measurement standards.

Table 2. *Quality Appraisal of Research Studies* (NA= non-applicable)

	Adriani & Moriber (2013)	Erdling & Johansson (2015)	Fettes et al. (2013)	Hooven (2011)	Horn et al. (2012)	Kramer (2013)	Nicholson (2013)	Perl et al. (2014)	Rowley (2014)	Shin et al. (2015)
Does the researcher identify what is known and not known about the problem and how the study will address any gaps in knowledge?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the purpose of the study clearly presented?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Was the literature review current (most sources within last 5 years or classic)?	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Was sample size sufficient based on study design and rationale?	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes
If there is a control group: Were the characteristics and/or	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes

demographics similar in both the control and intervention groups?										
If there is a control group: If multiple settings were used, were the settings similar?	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
If there is a control group: Were all groups equally treated except for the intervention group(s)?	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Are data collection methods described clearly?	No	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes
Were the instruments reliable (Cronbach's α [alpha] > 0.70)?	No	Yes	Yes	No	No	No	No	No	Yes	No
Was instrument validity discussed?	Yes	Yes	Yes	No	No	No	No	No	Yes	No
If surveys/ questionnaires were used, was the response rate > 25%?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Were the results presented clearly?	No	Yes	No	Yes	No	No	Yes	No	No	Yes
If tables were presented, was the narrative consistent with the table content?	Yes	Yes	Yes	Yes	Yes	NA	Yes	Yes	Yes	Yes
Were study limitations identified and addressed?	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Were conclusions based on results?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quality Rating Based on Quality Appraisal	Low	High	Good	Good	Good	Low	Low	Good	High	High

The final table presents an overview of what is known in the recent literature concerning how preoperative warming affects the incidence of UPH in adult patients undergoing general anesthesia. The table entails strength of the evidence-based upon study design and quality of the scientific evidence as graded by ©The Johns Hopkins University Nursing Evidence-Based Practice Appendix E: Research Evidence Appraisal Tool. It also includes purported results and conclusions of each study pertaining to the PICO question under review in this thesis, and the reviewer's critique and commentary regarding reliability of the findings.

Table 3. *Appraisal of the Evidence Ratings, Results & Conclusions, and Critique* (ANOVA= analysis of covariance; OR= operating room; PACU= post-anesthesia care unit; SD= standard deviation)

Evidence Strength /Quality	**Results/Conclusions Relating to PICO Question**	**Critique/Commentary**
Adriani & Moriber (2013) Strength: Level 2 Quality: Low	Repeated-measures ANOVA demonstrated a significant effect of time on temperature ($p < .001$), as well as a significant effect of each intervention across all 3 time periods ($p = .042$). However, no statistically significant difference found between groups with respect to body temperature over time ($p = .755$). Conclusion preoperative warming with Bair Paws gown offers no benefit over conventional therapy for maintaining normothermia and does not affect UPH incidence.	Findings may be unreliable, to be considered with extreme caution. Study did not meet stated intended purpose in effectively evaluating if prewarming plus intraoperative warming is more effective in the prevention of hypothermia than intraoperative warming alone, as anesthesia provider chose whether intraoperative forced-air warming blanket to be initiated without listing any criteria for initiation, and no statistical test performed to determine whether significant difference in the prewarmed versus non-prewarmed group in regard to intraoperative forced-air warming blanket use. Prewarming gown temperature controlled by patient to thermal preference, resulting in lack of temperature regulation to ensure effective prewarming. Mention of varying anesthesia providers throughout study as a limitation. OR mattress may or may not have been warmed. No control for OR ambient temperature and mention that wall thermostats in perioperative setting could be adjusted at any time by the staff producing much variability in the readings. Failure to discuss instrument reliability. Mention of varying staff persons obtaining temperature measurements. Staff training on correct use of equipment not discussed. Inconsistent temperature measurement instruments used throughout study (oral and esophageal). Time intervals for temperature measurements unclear and imprecise as no regulation by numerical intervals. Conclusions drawn regarding unclear/unlisted postoperative temperature results, as postoperative temperatures were not listed in results section table (narrative only states all subjects had a temperature >36°C when they arrived in the PACU, with no further numerical values reported).
Erdling &	At 210 minutes, statistically significant differences in temperature	Findings likely reliable. Study met stated intended purpose. Study lists limitations as: due to limitations in sample size,

Johansson (2015) Strength: Level 1 Quality: High	between prewarmed and non-prewarmed groups with both esophageal and nasopharyngeal measuring techniques: Esophageal: prewarmed 36.5 ± 0.6 versus non-prewarmed 35.8 ± 0.7 (mean ± SD in °C) (p= 0.001). Nasopharyngeal: prewarmed 36.7 ± 0.6 versus non-prewarmed 36.0 ± 0.6 (mean ± SD in °C) (p= 0.002). From anesthesia start to 210 minute mark, esophageal temperature in prewarmed group increased by 0.65 ± 0.63 (mean ± SD in °C) (p= 0.001). In the non-prewarmed group, this difference was smaller 0.27 ± 0.62 (mean ± SD in °C) and not statistically significant (p= 0.052). Conclusion prewarming for 42 minutes has a positive effect in preventing UPH and even shorter prewarming times may be of benefit for UPH prevention.	types of surgery, and anesthesia techniques, further limits generalizability to entire adult population undergoing general anesthesia. Beta-blockers and vasopressor medications used during anesthesia in prewarmed and non-prewarmed groups (no significant difference between the groups), causing vasoconstriction that may have lessened UPH incidence throughout the study. Patient conditions such as perfusion and tissue disorders may have affected results. Outflow temperature in the warming device varied considerably from the preset value of 43°C by -1°C to +5°C. It is possible placement of temperature probes varied from patient to patient and affected results although Mekjavic-Rempel formula used to ensure most accurate placement possible.
Fettes et al. (2013) Strength: Level 1 Quality: Good	The first question, "Will using forced- air warming techniques before surgery decrease the number of patients presenting to the PACU in a hypothermic state?" was not supported (p= 0.508). Additionally, no significant difference in the mean temperatures of prewarmed versus non-prewarmed patients after prewarming intervention was completed (p= 0.314). The second question "Will prewarming patients before surgery decrease the length of stay in the PACU?" was not supported. The median PACU times, 50 minutes for the prewarmed group and 49 minutes for the non-prewarmed group, were not statistically significant (p = 0.545). Conclusion prewarming does not significantly affect UPH incidence in regards to patient temperature on arrival to the PACU or PACU length of stay.	Findings likely reliable, to be considered with caution. Study met stated intended purpose. Inadequate sample size and failure to reach 64 subjects per group as determined by the power analysis. Study results are not invalidated, but the power of the study is lowered from its intended 80% power. No statistical test performed to identify differences between prewarmed versus non-prewarmed groups regarding surgery type. Both prewarmed and non-prewarmed groups received warm cotton blankets preoperatively (and some patients may have received multiple warmed cotton blankets from nurses upon request), confounding the effects of prewarming. Reported lack of patients with hypothermia in both the prewarmed and non-prewarmed groups throughout the study. No control for OR ambient temperature. Time intervals for temperature measurements unclear. Discussion of staff training regarding safe use of equipment, but no discussion of staff training on accurate temperature measurement. Time intervals for temperature measurements unclear and imprecise as no regulation by numerical intervals and does not give a complete clinical picture for UPH occurrence as intraoperative temperature measurements not evaluated. All results are not presented clearly, and does not present SD measure of central tendency in regards to temperature results (only presents mean temperature results).
Hooven (2011) Strength: Level 2 Quality: Good	Analysis of variance controlling for presurgical temperature and surgical duration demonstrated: A significant difference (p= 0.026) in PACU temperatures between prewarmed group 97.56 ± 0.79 and non-prewarmed group 96.79 ± 1.18 (mean ± SD in °F) and a non-significant difference (p= 0.052) in preoperative to PACU temperature change between the prewarmed group +0.18 ± 0.99 and non prewarmed group -0.92 ± 1.20 (mean ± SD in °F). In the	Findings may be reliable, to be considered with caution. Study met stated intended purpose partially. Study purpose sought to evaluate perioperative normothermia by PACU arrival temperature of 96.8-100.4°F (36-38°C). Study did not achieve efficient evaluation of perioperative period, which entails the entire operative period, as only preoperative and postoperative temperatures were recorded, neglecting UPH that may have occurred throughout the intraoperative period. Perioperative standards of care prior to initiation of prewarming quality improvement project unclear, so difficult to determine whether prewarmed and non-prewarmed groups treated equally with exclusion of the prewarming intervention. In regards to patient characteristics, mean surgery duration differed significantly

	PACU, 11.7% of prewarmed patients emerged with UPH as compared to 48.6% of non-prewarmed patients. Conclusion that prewarming using forced warm-air blankets decreases UPH incidence in patients receiving colorectal surgery and a change in practice was implemented in prewarming all colorectal surgery patients.	between prewarmed and non-prewarmed groups (p= 0.048). Preoperative temperatures prior to prewarming also differed significantly between the groups (p= 0.008). However, these variables controlled for when analyzing data with AVOVA. Failure to include prewarming device temperature. Failure to discuss instrument validity and reliability. Time intervals for temperature measurements imprecise as no regulation by numerical intervals. Staff training on correct use of equipment not discussed. Failure to adequately address study limitations.
Horn et al. (2012) Strength: Level 1 Quality: Good	At PACU arrival, percentage of hypothermic patients in each group were non-prewarmed: 69%; prewarmed 10 minutes: 13%, prewarmed 20 minutes: 7%; prewarmed 30 minutes: 6%. Repeated measures ANOVA for determination of time x prewarming interaction across the four treatment groups revealed a significant difference between non-prewarmed group and prewarmed groups. No significant difference between the three prewarmed groups (p= 0.540). Shivering incidence significantly less in prewarmed groups compared to non-prewarmed group. Conclusion that forced-air prewarming of 10, 20 or 30 minutes considerably reduced the risk of UPH and postoperative shivering in comparison to no prewarming. Recommendation of a standardized prewarming period of 10 minutes, or if possible 20 minutes.	Findings likely reliable, to be considered with caution. Study met stated intended purpose. Some participants pre-medicated with midazolam at anesthesia provider discretion with no statistical test for significant differences between the groups. Narrative states 4% of patients hypothermic on arrival to preoperative area and at increased risk of UPH development, with no mention of how these 4% were distributed across the 4 groups. Failure to discuss instrument validity and reliability. Staff training on correct use of equipment not discussed. Failure to list all results clearly including numerical p value results of statistical tests (except for one mentioned p-value). For the most part, only states tests are significant or non-significant within the narrative.
Kramer (2013) Strength: Level 2 Quality: Low	From the baseline preoperative temperature to the temperature taken after the prewarming intervention, the mean temperature difference between the prewarmed versus non-prewarmed group was an increase of 0.2°C in the prewarmed group. Intraoperatively, the prewarmed group exhibited less redistribution temperature drop and attained a temperature of 36°C more quickly after general anesthesia induction than the non-prewarmed group. Both groups continued to increase in temperature throughout the surgery duration and ended well above 36°C at the time of entry into the PACU. Conclusion prewarming with forced-air warming device is an effective way of reducing the degree of post-induction redistribution hypothermia and helps prevent UPH by normothermia maintenance.	Findings have no outright reason to be suspected as unreliable, but due to limited amount of information, to be considered with extreme caution. Study met stated intended purpose. Very brief and insufficient literature review. Insufficient information presented whether participant demographics, settings, and treatment were similar in both prewarmed and non-prewarmed groups. As there was no randomization to groups, these variables cannot be assumed to be equal between the groups. Insufficient description regarding perioperative settings of prewarmed and non-prewarmed groups: failure to include prewarming device temperature, no mention of control for OR temperature, instrument validity or reliability, or staff training on correct use of equipment. Inconsistent temperature measurement instruments used throughout study (oral and esophageal). Time intervals for temperature measurements unclear and imprecise as no regulation by numerical intervals.

Nicholson (2013) Strength: Level 1 Quality: Low	Student's t-test was used to estimate the standard error between the prewarmed and non-prewarmed groups. Temperatures measured in the preoperative, intraoperative, and postoperative intervals were not statistically significant between the prewarmed versus non-prewarmed groups. A chi-square test evaluating whether there was a difference in the proportion of UPH among prewarmed versus non-prewarmed groups across the preoperative, intraoperative, and postoperative intervals was not statistically significant. Conclusion prewarming did not reduce the proportion of patients who experienced subsequent hypo-thermia, and does not recommend a specific intervention for a prewarming strategy but indicates that prewarming may contribute to normothermia in the immediate postoperative period.	Findings may be unreliable due to major study flaw. Study did not meet stated intended purpose as it did not effectively evaluate a prewarming versus a non-prewarming intervention. The standard perioperative care for all patients in the study included use of a forced-air warming blanket or gown on entry to the OR and to maintain it *before* induction of general anesthesia, so participants in both control and intervention groups received prewarming. Failure to include prewarming device temperature. Differences in patient demographics between groups: more patients in prewarmed group underwent a cystoscopy or insertion of ureteral catheter before surgery versus patients in non-prewarmed group. Study mentions a few participants being hypothermic on arrival to preoperative area and at increased risk of UPH development, with no mention of whether these hypothermic patients were evenly distributed within the prewarmed and non-prewarmed groups. Intraoperative warming methods should have been standardized for both groups to isolate prewarming variable; narrative states majority of participants received certain intraoperative warming interventions, but no statistical test performed to determine significant differences between the groups. Failure to discuss instrument validity and reliability. Staff training on correct use of equipment not discussed. Time intervals for temperature measurements imprecise as no regulation by numerical intervals. Inconsistent temperature measurement instruments used throughout study (oral thermistor, nasal, esophageal, or rectal temperature probe or temperature-sensing urinary catheter). Inconsistency in narrative of results section where it states 32 patients/91% within the non-prewarmed group experienced hypothermia in the PACU (when there was a total of 32 patients in this group, incorrectly reported number or percentage as 32/32 is 100%, not 91%). Stated limitations: difficulty obtaining oral temperatures in immediate postoperative phase and lack of dedicated research assistants or co-investigators.
Perl et al. (2014) Strength: Level 1 Quality: Good	Core temperature in actively prewarmed group significantly higher compared to non-prewarmed group and passive prewarmed group at 15, 30, 45, 60, and 75 minutes post anesthesia induction (ANOVA) and at the end of surgery compared to the non-prewarmed group only (*post hoc* Scheffé's test). Core temperature in actively prewarmed group differed significantly up to 30 minutes after PACU admission compared with the passively warmed group and up to 40 minutes compared to the non-prewarmed group. Conclusion passive prewarming is ineffective, and active prewarming with a forced-air warming device and a reflective prewarming suit is effective in achieving significantly higher core temperatures intra- and post-operatively compared to conventional techniques. Findings emphasize intraoperative warming alone is not sufficient in preventing UPH.	Findings likely reliable, to be considered with caution. Study met stated intended purpose. Inadequate sample size (n=68 versus desired n=69) as determined by the power analysis. Study results are not invalidated, but the power of the study is lowered from its intended 80% power. Failure to include prewarming device temperature. Failure to discuss instrument validity and reliability. Staff training on correct use of equipment not discussed. Inconsistent temperature measurement instruments used throughout study (oral and esophageal). In regards to intraoperative warming, some participants received a forced-air warming upper body blanket while some received a lower body blanket depending on surgical procedure and no statistical test to determine significant difference between the prewarmed and non-prewarmed groups. Failure to list all results clearly including numerical *p* value results of statistical tests, only states tests are significant or non-significant within the narrative.

Rowley (2014) Strength: Level 2 Quality: High	No significant statistical differences in postoperative core body temperatures among the four groups: 1) routine surgical care group 2) prewarmed with forced-air warming only 3) prewarmed with forced air warming and ambient OR temperature increased 4) ambient OR temperature increased only. No significant difference between pre- to post- core body temperatures for each group. Although patient temperatures varied over the perioperative time period, conclusion prewarming interventions were not more effective than the current routine surgical care in preventing UPH.	Findings likely reliable, to be considered with caution. Study met stated intended purpose. Staff training on correct use of equipment not discussed. Time intervals for temperature measurements imprecise as no regulation by numerical intervals. Failure to list all results clearly including numerical *p* value results of statistical tests, only states tests are significant or non-significant within the narrative. Stated limitations: challenges in achieving the desired ambient surgical room temperature of 21.1°C (70°F) for some cases and need to statistically correct for a room temperature of 20°C (68°F) in data analysis. Estimated blood loss was not included in the data collection, which could have affected a patient's tendency to experience hypothermia.
Shin et al. (2015) Strength: Level 1 Quality: High	For prewarmed and non-prewarmed groups, significant drop in core temperature from intubation to 20, 40, 60, 80, 100, and 120 minutes post intubation. (p= 0.007 at 20 minutes post intubation in prewarmed group, p< 0.001 at the other all times in both prewarmed and non-prewarmed groups). Core temperatures of prewarmed group significantly higher than those of non-prewarmed group at 20, 40, 60, 80, 100, and 120 minutes post intubation (p < 0.001 at all times). Incidence of UPH significantly lower in prewarmed versus non-prewarmed group at 20, 40, 60, 80, 100, and 120 minutes post-intubation (p= 0.002 at 20 minutes, p< 0.001 at other times). Mean core temperature of pre-warmed group maintained above 36°C until 80 minutes post-intubation. No significant difference (p= 0.283) observed in PACU shivering between prewarmed and non-prewarmed groups. Conclusion prewarming should be considered as part of the anesthetic management for patients undergoing coiling of aneurysm at risk of hypothermia in a cold environment.	Findings likely reliable. Study met stated intended purpose. Failure to discuss instrument validity and reliability. Staff training on correct use of equipment not discussed. Inconsistent temperature measurement instruments used throughout study (tympanic and esophageal). Study notes a limitation as the warming device indirectly affecting tympanic membrane temperature and causing inaccuracy of core temperature measurement with the infrared tympanic thermometer, so the highest value of 3 consecutive measurements was recorded to decrease error and the study relied more heavily upon esophageal temperature as an accurate measurement of core temperature. As the temperature readings at intubation were taken with the infrared tympanic thermometer, results concerning significant drop in core temperature for both groups from intubation to 20, 40, 60, 80, 100, and 120 minutes post intubation may be unreliable. As other results were based upon comparison of esophageal temperatures between the prewarmed and non-prewarmed groups, these results can still be considered reliable.

Limitations

Although ©The Johns Hopkins University Nursing Evidence-Based Practice Appendix E: Research Evidence Appraisal Tool is a valid evidence-rating instrument, there are some limitations in regards to use of this tool. The purpose of a grading tool is

to assist the researcher in determining whether statements about clinical practice are based on research or other reliable evidence. According to Boswell and Cannon (2014), as of 2011, there were over 40 available evidence-rating methods/tools; thus, there is a lack of standardization in regards to a consistent system for evidence appraisal of nursing research. Without a uniform means of evaluating the evidence, communication of the nature of the evidence is confusing and disoriented. For example, there are numerous scales for the levels of evidence varying from three levels to as many as seven levels, and also a lack of standardization in regards to definitions of levels of evidence (Boswell & Cannon, 2014).

©The Johns Hopkins University Nursing Evidence-Based Practice Appendix E: Research Evidence Appraisal Tool utilizes only three levels to grade the strength of the evidence in regards to each source's study design as an experimental, quasi-experimental, non-experimental, or a qualitative study. Other evidence appraisal tools utilizing up to 7 levels of evidence consider case reports, clinical expertise, or expert opinion in grading of the evidence. As ©The Johns Hopkins University Nursing Evidence-Based Practice Appendix E: Research Evidence Appraisal Tool does not include these types of sources for consideration in rating the level of evidence, the use of this tool hindered some current sources of information from being included in the review that could have revealed pertinent information regarding the PICO question under evaluation.

Similarly, the integrative review approach taken to analyze the data limits the types of sources to be included in the review to quantitative studies only, further hindering the inclusion of case reports, clinical expertise, or expert opinion that could have potentially added insight to the review. In addition, the quality rating in grading

each source as high, good, or low presents room for human error as these are somewhat subjective decisions made by the grader. For example, the tool uses terms for quality grading such as *consistent*, *reasonably consistent*, and *little evidence with inconsistent results* to grade a source as high, good, or low. As there is no exact criteria to differentiate *consistent* versus *reasonably consistent*, this presents room for error in accurate grading of the quality of the evidence.

In regards to the ten studies included in the review, six are experimental in design and utilize randomized controlled trials while four are quasi-experimental in design and utilize controlled trials without randomization. The quasi-experimental study design is a limitation in weakening the strength of the study results. Additionally, most studies utilize convenience sampling of adult patients within a particular hospital or healthcare setting rather than random sampling of the entire adult population undergoing general anesthesia, limiting the generalizability of the results to all adults undergoing general anesthesia. However, this limitation is largely unavoidable; a study design utilizing random sampling of the entire adult population undergoing general anesthesia would be very difficult to achieve as variables such as perioperative characteristics, standards of care, and instruments would need to be uniform across all settings to effectively isolate the independent variable of prewarming.

Another limitation is inability to consistently compare and contrast results of the ten studies due to varying study characteristics. For example, inclusion/exclusion criteria differ for each study. These criteria include study participants falling within a certain ASA class, BMI range, preoperative temperature range, requiring an elective versus an emergency surgery, and undergoing a specific type of surgical procedure. For example,

two studies required participants to be ASA classes I-II, three studies required classes I-III, one study required classes I-IV, and four studies listed no ASA criteria for inclusion. Three studies required participants to be within a certain BMI range for inclusion. Six studies required participants to be within a certain preoperative temperature range. Most of the studies required study participants to be undergoing elective surgeries, and each study evaluated different types of surgical procedures. It is plausible patients who were excluded, many due to obesity and other comorbid conditions, may have had differing trends in regards to thermoregulation and response to a prewarming intervention. As the prevalence of obesity and other comorbidities are largely present within the entire adult population, excluding these types of patients as study participants further limits the generalizability of study findings to all adults undergoing general anesthesia.

As each type of surgical procedure tends to embody fairly consistent characteristics such as duration, surface area of body exposed intraoperatively, expected blood loss, and so on, surgery type likely affects study results in regards to perioperative temperature. Half of the studies examine adults undergoing a specific type of surgical procedure, such as colorectal procedures only. The other half of the studies examine adult participants undergoing various types of surgeries; for example one study examines adults undergoing abdominal procedures, total hip and knee replacements, and lumbar spinal fusion procedures. Of the studies examining one specific type of surgical population, the independent variable of prewarming is better isolated, but the results are not as generalizable to the entire adult population undergoing general anesthesia. Of the studies that include participants undergoing various types of surgeries, results are more generalizable to the entire adult population undergoing general anesthesia; however, the

study must ensure an equal distribution of surgery types to the prewarmed and non-prewarmed groups, which should most likely be achieved if participants are randomly assigned to groups. A limitation exists if there is unequal distribution of surgery types to the prewarmed and non-prewarmed groups, which may have been possible in the studies with a quasi-experimental design. Another limitation to most of the studies is inconsistency in time of day surgical procedures took place. Only one study by Erdling & Johansson accounted for circadian variation in body temperature as a confounding variable by ensuring all surgical procedures included in the study took place at 7:30 AM.

Sample sizes vary throughout the studies ranging from 24 to 220 study participants. A few studies list a limitation as inadequate sample size. Two of the studies by Fettes et al. (2013) and Perl et al. (2014) did not reach intended sample size based on the power analysis. By failing to reach the required sample size for the desired power, the results of these studies are not necessarily invalidated, but ability to detect an effect between the groups is lessened, and study results are therefore not as strong as the intended power. A few of the studies list a limitation as unequal distribution of study participants between the control and intervention groups, as participants were randomized into groups and later had to be withdrawn from the study due to various reasons.

Most of the studies identify the inability to perform blinded trials as a limitation to their design. As all patients were ethically required to give informed consent to study participation and to be informed of the possible interventions to occur, whether he/she received the prewarming intervention or was placed in the control group with no prewarming intervention was quite obvious to the individual, preventing the use of subject blinding. In regards to blinding of the investigators (the healthcare providers or

researchers) during the preoperative phase in which the prewarming intervention was performed, blinding was difficult to achieve. However, during the intraoperative and postoperative phases, the investigators were able to be blinded as to whether a participant received prewarming or not for most of the studies.

While most of the studies list a precise duration or a minimum number of minutes of prewarming to be achieved, only one study by Horn et al. (2012) discusses the use of a countdown timer to ensure desired amount of prewarming was actually achieved. Of the studies requiring a minimum number of minutes of prewarming to be achieved rather than a precise amount of time, a limitation is lack of standardization in regards to minutes of prewarming for each participant, potentially affecting results. Another limitation is that most of the studies do not control or account for the number of minutes following prewarming to anesthesia induction. Only one study by Horn et al. (2012) reports the time in minutes between end of prewarming and start of anesthesia induction and performs statistical tests to ensure that this time is comparable between the control and intervention groups.

While some studies identify a limitation as varying surgical teams used throughout the duration of the study, other studies fail to discuss this aspect or to address it within the limitation section, suggesting this variable was likely uncontrolled for. Each surgical team, consisting of a surgeon, anesthesia provider, and other perioperative staff utilizes different standards of care to a degree. For example, across the studies, anesthesia providers utilized differing intraoperative warming techniques including various passive warming and active warming devices for certain durations and temperatures, warmed irrigation and IV fluids, and humidified anesthetic gases. A major limitation to a few of

the studies is inconsistent use of intraoperative warming methods with no performance of statistical tests to ensure warming methods were comparable between the control and intervention groups. In order to effectively compare the effects of prewarming versus no prewarming it is imperative all variables, especially temperature related variables such as intraoperative warming techniques, be standardized for all study participants. Some studies discuss the initiation of intraoperative forced-air warming only once participants dropped below a certain core temperature, creating standardization for all participants. However, some studies do not include this criteria and state forced-air warming was initiated at anesthesia provider discretion, creating variability and uncertainly as to whether intraoperative warming methods were standardized between the control and intervention groups, potentially discrediting study results as in the case of the study by Adriani and Moriber (2013).

Moreover regarding variability between surgical teams, each anesthesia provider has the autonomy to choose various anesthesia administration techniques and medications for each patient on an individualized basis. In the study performed by Horn et al. (2012), some study participants were pre-medicated with midazolam at anesthesia provider discretion, which may have interfered with hypothalamic thermoregulatory mechanisms and affected perioperative temperatures. Likewise, surgeons have the autonomy to choose various medications, incision types and sizes, and fluids/blood products administered that may impact core temperature. Surgeons also largely control the duration of surgery by the rate they work at, affecting total patient time under general anesthesia and further affecting core temperature results. The study performed by Adriani and Moriber (2013) describes some study participants receiving OR mattress warming while others may not

have received this warming intervention. A few studies reported nurses giving patients extra warmed blankets upon request in the preoperative area, potentially affecting perioperative temperatures.

Only one study by Rowley (2014) discusses the exclusion of study participants who required or requested additional warming measures throughout the perioperative period. Some studies identify a limitation as varying researchers and/or staff members taking temperature readings throughout the preoperative, intraoperative, and postoperative phases, introducing room for error in variation of thermometer probe placement and temperature readings. In addition, most studies fail to mention or implement the training of research personnel and/or staff members in the correct use of equipment. In a few studies, researchers experienced difficulty or were unable to obtain participant temperatures in the immediate postoperative period due to complications related to the surgical procedure or need for immediate patient transfer to the intensive care unit (ICU) versus the PACU.

In regards to the core temperature measurement device, only four of the ten studies provide an adequate discussion of instrument validity, and only three studies include a discussion regarding instrument reliability by ensuring instrument calibration and testing by the facility's Bio-Medical Department to confirm function at the beginning of the study and throughout the study duration at intervals recommended by the equipment manufacturers. The study by Shin at al. (2015) discusses a limitation as core temperature measurements taken by an infrared tympanic thermometer being indirectly affected by warm air blowing from the forced air-warming device, a limitation that may

have been present yet unaccounted for in the other studies utilizing infrared tympanic thermometers such as the studies by Hooven (2011) and Horn et al. (2012).

In regards to control of ambient OR temperature, most studies relied on the wall thermostat or a temperature probe placed within the OR to ensure the temperature remained within the set limits. Three studies did not report or control for ambient OR temperature whatsoever. While the remaining seven studies reported OR temperatures, some did not control the temperature but merely reported it. Of the studies that did attempt to control OR temperature, some studies listed a limitation as difficulty in achieving the desired ambient OR temperature and ensuring that intraoperative staff did not adjust the temperature thermostat throughout the study duration. Only two studies by Erdling & Johansson (2015) and Shin et al. (2015) discussed ambient OR temperature being read at a site not affected by warming devices and recorded at the same intervals as core temperature.

Five of the ten studies fail to discuss control of the prewarming device temperature to ensure standardization and effectiveness of the prewarming intervention. In the study by Adriani and Moriber (2013), prewarming gown temperature was controlled by the patient to his/her thermal preference, resulting in uncontrolled temperature regulation to ensure effective prewarming. Only two studies discuss reliability of the prewarming device. The study by Erdling & Johansson (2015) confirmed reliability by placing a valid thermometer probe in the warming equipment and measuring whether the device remained at the intended temperature periodically throughout the trial duration. The study by Rowley (2014) confirmed reliability by

having the Bio-Medical Department test and confirm prewarming blanket function, safety, and measurement standards prior to beginning the study.

In regards to description of data collection methods, a few studies are unclear in describing time intervals for core temperature measurement. While four studies designate time intervals as quantitative values, six studies describe time intervals as qualitative values such as preoperative, intraoperative, and post-operative temperatures. The use of quantitative time intervals ensures temperature is measured at consistent times for all participants throughout the study, eliminating the confounding effect of time on temperature. The use of qualitative time intervals creates more room for variability in the time window temperature is recorded within. For example, the intraoperative period lasted anywhere from 30 minutes to greater than 210 minutes across the studies, so an intraoperative temperature could indicate a temperature measurement at 30 minutes or 210 minutes following induction of general anesthesia, creating great variability in temperature results. Some articles state a study objective as evaluating UPH occurrence, yet failed to evaluate or record intraoperative temperatures throughout the study. Perioperative hypothermia entails hypothermia occurring anytime throughout the preoperative, intraoperative, or postoperative periods. These studies made claims and conclusion as to UPH occurrence, yet failed to effectively evaluate temperatures across the entire perioperative period as UPH could have occurred unaccounted for during the intraoperative period.

Another limitation is inconsistency in type of instrument used to measure core temperature. For example, in four studies, preoperative and postoperative temperatures were recorded via an oral thermometer while intraoperative temperatures were recorded

via an esophageal thermometer. Five studies used the same *type* of instrument to record core temperature throughout the perioperative period, but only three of these studies likely ensured the same thermometer accompanied patients throughout the entire study. Only one study by Rowley (2014) clarified in the narrative the same thermometer accompanied patients throughout the entire study to ensure consistency and accuracy of temperature readings. A few articles fail to present study results clearly and/or provide scant information in comparison to other studies that present detailed descriptions of results including multiple measures of central tendency and numerous tables and graphs. While some studies mention statistical tests as being significant or non-significant within the narrative, they fail to include the data concerning these tests and/or the test results in terms of *p* value, limiting the researcher's interpretation of statistical test results.

Gaps

Most of the studies identify gaps in the knowledge base and suggest areas for further research concerning prewarming. Nearly all of the studies that found prewarming to be effective in UPH prevention suggest researchers should repeat their study design with a strengthened approach by reducing identified limitations, increasing the sample size, and expanding study trials to various types of patient populations. One study by Fettes et al. (2013) that found prewarming to be ineffective does not recommend further research on prewarming, but suggests that research be directed towards the most effective intraoperative warming techniques and the effects of adequate warming on long-term patient complications such as postoperative infections. Another study by Rowley (2014) that found prewarming to be ineffective suggests further research be conducted that

examines bundled patient care factors in the prevention of UPH using randomized control designs.

Only a few of the studies address the safety of prewarming with the primary concern being an overheating of the warming device and resultant burning of the patient. In the study by Erdling and Johansson (2015), patient skin temperatures were obtained from probes positioned on the calf and upper thorax to detect any overheating from the warming device. In the study by Fettes et al. (2013), safety features such as self-test sequences, temperature alarms, system failure turn-off devices, higher than programmed temperature shutdown circuits, and mechanisms to verify temperature output were in place to ensure warming blankets were reliable and safe for use. The study by Horn et al. describes study participants being assessed every 5 minutes throughout the prewarming duration for thermal comfort and the warming device being lowered from 44 °C to 40 °C if the patient reported feeling overheated. The study by Shin et al. (2015) utilized the medium temperature setting for prewarming devices to avoid potential patient burns from a higher temperature setting, yet the study states forced-air warming blankets should not produce burns when used appropriately. As the remaining six studies fail to consider or discuss patient saftety in regards to prewarming, future studies should ensure the safety of warming devices are addressed when working with human research subjects.

The type of warming device used for prewarming is inconsistent across the ten studies. The types of warming devices include *Bair Paws* forced-air warming gown, *Bair Paws* forced-air warming blanket, *Snuggle Warm* forced air-warming blanket, *Warm Tou*ch forced air-warming device, *Gaymar* forced air-warming device, and *Mistral-Air Premium* warming suit. A few studies do not list the warming device manufacturer and

only state a forced-air warming gown or blanket is used. The studies describe the body surface area covered by these warming devices with descriptions such as full body gown, full body blanket covering the patient's anterior surface, upper body blanket, or lower body blanket. One study by Erdling et al. describes a prewarming device covering the patient's head, thorax, and both arms. The studies utilize temperature settings of these warming devices ranging from 37-44°C. Future studies should explore which type of prewarming device, body surface covered, and temperature settings are most effective in the prevention of UPH. Additionally, future studies should ensure standardization of intraoperative warming methods for all participants or ensure an equal distribution of intraoperative warming methods to the control and intervention groups to effectively isolate the independent variable of prewarming.

Another gap is the most valid and reliable type of thermometer for core temperature measurement. The studies utilize various instruments including oral, esophageal, nasopharyngeal, tympanic membrane, rectal, temporal artery, and temporal lobe infrared probe thermometers and temperature-sensing urinary catheters. According to *ASPAN'S Evidence-Based Clinical Practice Guideline for the Promotion of Perioperative Normothermia* (Hooper et al., 2010), there is strong evidence to suggest the most accurate site in approximating core temperature is oral, and that the same route of temperature measurement should be used throughout the perioperative period for consistency and comparison purposes. There is also weak evidence to suggest temporal artery measurements approximate core temperature accurately at normothermic temperatures but not at extremes outside of normothermia. There is additionally weak evidence to suggest an infrared sensor at the tympanic membrane does not provide

accurate temperature measurements during the perianesthesia period. Further research is warranted in confirming the most accurate technique for core temperature measurement in order to effectively isolate the independent variable of prewarming.

The study by Erdling and Johansson (2015) sought to compare esophageal and nasopharyngeal temperatures measured in the same patient throughout the perioperative period while randomly assigning half of the study participants to receive a prewarming intervention. The study results demonstrate a significant difference between the esophageal and nasopharyngeal core temperature measurements, with the esophageal measurement technique being more sensitive to changes in core temperature than the nasopharyngeal technique. These results suggest esophageal temperature measurement is more accurate than nasopharyngeal and that inconsistent temperature measurement techniques may produce unalike temperature readings, suggesting the instrument for temperature measurement should be standardized throughout study duration in future research trials to ensure temperature measurement accuracy.

Another gap in the knowledge base is how to best implement prewarming into daily clinical practice, as its cumbersome nature often hinders its routine implementation. Most studies required at least 30 minutes of prewarming time, rendering prewarming a time consuming intervention within the preoperative phase of care. Following, the preoperative staff can find it burdensome and disturbing to the surgical preparation process to carry out prewarming interventions and to educate patients about warming devices prior to surgery in addition to other job responsibilities. Thus, future studies should explore convenience and space for care concerning prewarming. There is also lack of consensus across the studies concerning the minimal amount of prewarming time

needed to effectively reduce UPH. Of the seven studies that conclude prewarming to be effective in the prevention of UPH, the duration of prewarming time ranges from 10 minutes to 131 minutes. Thus further research needs to address the minimum duration of prewarming that is still effective in UPH prevention. The study by Horn et al. demonstrates prewarming durations as short as 30, 20, and 10 minutes to be effective in reducing UPH, so more studies evaluating these shorter prewarming durations need to be conducted for various patient populations to confirm efficacy.

A few studies note a reported decrease in anxiety and overall greater comfort levels in patients receiving prewarming. Furthermore, studies regarding patient satisfaction and perspective of preoperative warming may be valuable. As the implementation of prewarming brings additional hospital costs, although very small, the cost-effectiveness of prewarming is another gap that needs to be explored. According to Fettes et al. (2013), implementing a prewarming protocol has the potential to increase costs from increased nursing activity and warming blanket replacement costs because the blankets would be used for longer periods. Additionally, as some types of warming devices can be used both preoperatively and intraoperatively as the warming blanket or gown remains on the patient following the preoperative period and is reconnected to a warming system intraoperatively, the convenience and cost savings of these types of devices should be evaluated versus use of disposable warming devices or separate preoperative and intraoperative warming devices.

The article by Erdling and Johansson (2015) addresses the concern of warming devices following the patient from the preoperative area to the intraoperative area as a potential source of contamination, increasing risk for surgical site infections. The article

goes on to discuss that most warming equipment has bacterial filters to prevent organism transmission, but there may be a need for improved intake filtration in order to reduce contamination and emission risks. Future studies could evaluate the risks of increased surgical infection rates with prewarming devices. One study by Nicholson (2013) addresses the lack of dedicated research assistants or co-investigators there were to conduct the study. As the study was conducted by a nurse manager and nurse practitioner, the article describes the difficulties of balancing job responsibilities with experiment conduction and resulting study limitations. The nurse researchers occasionally missed opportunities to obtain consent from potential study participants or to fully implement study protocols when called away from the research bedside to other nursing duties. When the nurse researchers could not assist with multiple study participants on a particularly busy admission day, some participants did not receive the prewarming intervention and had to be excluded from the study. Following, more time, money, and effort must be devoted to prewarming research to effectively conduct high-quality studies as the shift towards evidence-based practice becomes greater. According to Rowley (2014), "It is essential that clinical staff are involved in evidence-based practice and quality management activities that incorporate mentorship, expert knowledge, outcomes management, patient care, and institutional factors as a broad strategy to further promote evidence-based practice in this area" (p. 439).

Discussion

Of the ten studies, three are graded as low quality, defined by ©The Johns Hopkins University Nursing Evidence-Based Practice Appendix E: Research Evidence Appraisal Tool as, "little evidence with inconsistent results, insufficient sample size for

the study design; conclusions cannot be drawn." The study by Adriani & Moriber (2013) is graded as low quality due to a major study flaw, as there was unequal treatment of the control and intervention groups excluding the prewaming intervention in regards to intraoperative warming methods. The study by Kramer (2013) is graded as low quality due to insufficient information regarding equal treatment of the control and intervention groups; as the study design is quasi-experimental without random assignment of subjects to groups, this further decreases the likelihood the variables of participant demographics, settings, and treatment were similar between the groups. The study by Nicholson (2013) is graded as low quality due to a major study flaw, as prewarming was unintentionally implemented for every study participant in both the control and intervention groups, negating comparison of the effects of the prewarming variable. While the studies by Adriani & Moriber (2013) and Nicholson (2013) conclude prewarming makes no difference in the occurrence of UPH, the study by Kramer concludes prewarming is an effective measure in the prevention of UPH. However, due to their low quality ratings, these three studies will not be considered when drawing a final conclusion as to the effect of prewarming in UPH occurrence.

Among the remaining seven studies graded as good or high quality are the studies by Erdling & Johansson (2015), Fettes et al. (2013), Hooven (2011), Horn et al. (2012), Perl et al. (2014), Rowley (2015), and Shin et al. (2015). Of these seven studies, five conclude prewarming is an effective measure in decreasing UPH incidence, while two studies by Fettes et al. (2013) and Rowley (2015) conclude prewarming makes no difference in the occurrence of UPH. Thus, the majority of the good or high quality studies claim prewarming is an effective measure in decreasing UPH incidence.

Additionally, implementation of prewarming presents few risks besides the cost. Across the ten studies, there were no reports of injury or harm to any of the prewarmed patients. A few studies raised concerns for safety pertaining to potential skin burns from the heat of warming devices and the potential for warming device organism transmission and increased patient surgical site infection, but there was no evidence of or manifestation of these problems throughout the ten studies. Therefore, the benefits of prewarming likely outweigh the risks, though more studies exploring the cost-benefit analysis of prewarming are warranted.

Conclusion

Consistencies and contradictions are found within the various articles under review. While some studies claim there is strong evidence to suggest prewarming adult patients undergoing general anesthesia deceases UPH incidence, other studies claim prewarming makes no difference in UPH occurrence, while some studies are graded as low quality and cannot be relied upon as producing reliable results based on quality scientific evidence. It is difficult to make a definitive conclusion regarding the effects of prewarming on UPH occurrence that can be generalized to the entire adult population undergoing general anesthesia, as this review considers articles describing studies in which specific adult populations are studied in regards to type of surgical procedure, ASA classification, BMI, and preoperative temperature criteria. There are also inconsistencies across the studies in regards to study design and characteristics, making it difficult to compare and contrast study results consistently. Despite these potential problems, most of the evidence supports the implementation of prewarming as an effective measure in decreasing the incidence of UPH. There is also evidence to suggest

prewarming presents a greater benefit than risk to the patient, and should therefore be more widely considered for regular implementation by healthcare providers to improve patient outcomes.

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