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Preoperative Forced-Air Warming of Patients to Minimize Inadvertent Perioperative Hypothermia: A Systematic Review

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A Major Paper Presented

by

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Abstract

Inadvertent perioperative hypothermia (IPH) occurs in many patients during surgery and can potentially carry serious complications, including cardiac arrhythmia, myocardial infarction, increased bleeding, impaired drug metabolism, impaired wound healing and increased risk of wound infection. There are many different techniques to minimize hypothermia during the perioperative period, but forced-air warming is used for many surgical patients. Forced-air warming has been shown to be effective during the intraoperative period; however, many institutions do not utilize this therapy in the preoperative setting. A systematic review was conducted to assess the use of preoperative forced-air warming and its' effects on minimizing IPH. Databases were searched for pertinent articles regarding the topic of study. Inclusion and exclusion criteria were used to finalize the articles to be included in the systematic review. A total of six studies were critically analyzed. Overall, forced-air prewarming of patients undergoing surgery helped to minimize IPH in adult surgical patients undergoing general anesthesia. Even in studies that did not demonstrate statistically significant results, findings demonstrated that patients that were preoperatively forced-air warmed were less hypothermic than those not prewarmed. Maintaining intraoperative forced-air warming, educating other health care providers about the effects of IPH, and advocating for preoperative warming are important topics that the advanced practice nurse, particularly the CRNA, can lead.

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Preoperative Forced-Air Warming of Patients to Minimize Inadvertent Perioperative Hypothermia: A Systematic Review

Background/Statement of the Problem

One of the many responsibilities of the Certified Registered Nurse Anesthetist (CRNA) is to actively monitor many different aspects of the patient during the perioperative period. Temperature monitoring is part of the American Society of Anesthesiologists (ASA) standards of care. Standard II requires that all patients receiving anesthesia will have temperature monitored when clinically significant changes in body temperature are anticipated, suspected and occasionally intended (ASA, 2010). There also exist standards of care regarding temperature for nurse anesthetists through the American Association of Nurse Anesthetists. Standard 5, subset B requires the CRNA to maintain normothermia through monitoring and anticipating clinically significant changes in body temperature (Standards for Nurse Anesthesia Practice, 2013).

Hypothermia is defined as a core body temperature less than 36° C (Kurz, 2008). Unintended decrease in core temperature during the perioperative period is considered inadvertent perioperative hypothermia (IPH). Many factors contribute to IPH such as the cold environment, cold intravenous fluids, anesthetics that inhibit temperature regulation of the patient, redistribution of heat to peripheral tissues and cold anesthetic gases. This occurs in potentially 50% to 70% of patients undergoing surgical procedures that require the initiation of general anesthesia (Roberson, Dieckmann, Rodriguez, & Austin, 2013).

The complications potentially associated with IPH can be detrimental for the patient. Decreased metabolic rate, decreased cardiac output, metabolic acidosis, prolongation of muscle relaxants, altered clotting functions, postoperative shivering and

an increased incidence of postoperative infection are some of the potential adverse effects of IPH and are associated with increased morbidity (Roberson et al., 2013). Certified registered nurse anesthetists need to be diligent in monitoring, preventing and treating IPH. One way to manage this is through forced-air warming units (Andrzejowski, Hoyle, Eapen, & Turnbull, 2008). These warming devices can directly heat the patient from a warm blanket that can be utilized throughout the perioperative period. The cost of these warming units can be a potential issue for institutions. If a preoperative area has several beds, this could potentially cost the institution thousands of dollars.

The purpose of this project was to complete a systematic review related to prevention of inadvertent perioperative hypothermia (IPH) in adult patients undergoing general or neuraxial anesthesia using forced-air warming systems, specifically during the preoperative period, as compared to intraoperative warming techniques alone. The end point assessed will be perioperative temperature measurement.

Next, the review of the literature will be presented.

Literature Review

Academic Search Complete, CINAHL Plus and Medline databases were searched. Search terms used independently and in combination included: inadvertent perioperative hypothermia; hypothermia; perioperative; perioperative hypothermia; forced-air warming; warming; preoperative; and temperature. Studies published within the past 10 years (2007-2017) that met other inclusion criteria were included in the systematic review articles. Due to the fact that prewarming is a relatively newly tested idea and still not used utilized in a majority of institutions today, many of the relevant studies have been published within the past 10 years.

Hypothermia

Hypothermia is defined as core body temperature less than 36 °C (Kurz, 2008). As early as 1860, a physician named Carl Wunderlich measured the temperature of thousands of patients and found the mean normal body temperature to be 37 °C (Torossian et al.,2015). Normal body temperature has been defined as temperature between 36 °C and 37.5 °C, and a temperature less than 36 °C is considered hypothermia (Kurz).

Hypothermia can result from prolonged cold temperatures, either atmospheric or submersion. Even those who are relatively healthy can develop hypothermia under the right conditions (Grossman & Porth, 2013). Heat is lost from the body in four different ways: radiation; conduction; convection; and evaporation (Miller et al., 2015). All surfaces with a temperature higher than absolute zero radiate heat and all surfaces also absorb radiative heat from surrounding surfaces, such as a patient's body and air. Radiation is most likely the primary culprit in heat loss in the surgical population. Conduction is the heat lost proportional to the temperature when two adjacent objects

are in contact. In the operating room, the patient is placed on a foam pad, which is an excellent thermal insulator and little heat is lost to the table. Convection is described as the heat lost to air molecules from flow of air that disrupts the layer of still air next to a surface, such as skin. Convection is dependent on air speed, and in the operating room, air speed is approximately only 20 cm/second, a small increase in heat loss compared to still air. It is the second most important mechanism of heat loss in the operating room, but due to surgical drape use, heat loss from convection is minimal. The final mechanism of heat loss is evaporation. Evaporation is the loss of water molecule from the skin, which causes heat loss. Sweating greatly increases evaporation and heat loss, but is rare during anesthesia. Evaporative heat loss from the skin surface accounts for less than 10% of metabolic heat production in the adult population; children and especially premature infants have a greater percentage. Based on some clinical measurement and thermodynamic calculations, only small amounts of heat are lost from the respiratory system. Evaporation only accounts for a trivial amount of heat loss in patients undergoing surgery. These four mechanisms of heat loss can contribute to body temperature less than 36° C, or hypothermia (Miller et al.).

Hypothermia during the perioperative period

Hypothermia can occur due to several factors, however it occurs in the operating room due to many interventions that are implemented by the health care team. Vasoconstriction is inhibited at the induction of anesthesia due to volatile anesthetics and core body temperature cannot be maintained (Guedes Lopes, Sousa Magalhães, Abreu de Sousa, & Batista de Araújo, 2015). Temperature of the operating room based on the surgeon’s preference, temperature of intravenous fluids and the length of surgery

are factors that can also contribute to hypothermia in the perioperative period (Guedes Lopes et al.). Anesthetics not only cause vasodilation, but also reduce the metabolic rate anywhere from 20% to 30%. The combination of vasodilation and decreased metabolic rate does not fully account for the 0.5° C to 1.5° C decrease usually seen during the first hour of anesthesia (Miller et al., 2015). This is partially due to the uneven distribution of core body temperature, where half the body mass, mostly the head and trunk, represents core temperature. The remaining mass, arms and legs, are typically 2° C to 4° C cooler than the core (Miller et al.). There are several reasons for hypothermia during the perioperative period, but these physiological changes that occur during the induction of anesthesia facilitate the loss of heat from the patient and accentuate the risk of hypothermia.

Neuraxial anesthesia, spinal and epidural, can also lead to IPH (Adriani & Moriber, 2013). Regional anesthetic medications are injected into either the subarachnoid space or epidural space and provide anesthesia to the patient in the areas below and slightly above the injection area. The patient will not consciously feel cold, but the body will be in a hypothermic state (Miller et al., 2015). Because it is not general anesthesia, the body's autonomic systems can respond to the drop in core temperature. Vasoconstriction and shivering can occur in areas that are not anesthetized by the regional block, but are decreased by 0.6° C. The vasoconstriction and shivering thresholds are comparably decreased during regional anesthesia, a finding suggesting an alteration in central, rather than peripheral, control (Miller et al.). Sedation and analgesic medications are usually supplemented along with neuraxial anesthesia and also impair thermoregulatory control. Few patients undergoing neuraxial anesthesia have

temperature monitoring throughout the perioperative period. Therefore, undetected hypothermia and adverse effects may be evident in this population (Miller et al.).

There are also individualized risk factors that may make the patient more susceptible to hypothermia. Young or old age, low body mass index, trauma, sepsis, burns and perioperative hypotension are elements that carry a greater risk of hypothermia (Guedes Lopes et al., 2015). During the perioperative period, many characteristics and factors may be present that can increase the incidence of IPH in patients undergoing general anesthesia and surgery

Complications associated with perioperative hypothermia

The occurrence of inadvertent perioperative hypothermia is a significant aspect of the perioperative period due to the potential complications that may result from it; therefore, it must be quickly identified, carefully monitored and treated accordingly. Some of the more severe complications due to hypothermia are cardiac arrhythmias, myocardial infarctions, increased bleeding due to coagulation disorders, drug metabolism inefficiency, impaired wound healing, greater incidence of infection in wounds and pressure ulcers (Torossian et al., 2015). These complications clearly have a negative influence on postoperative patient outcomes, as well as increased cost of treatment and extended length of stay.

Potentially the most dramatic adverse reaction that can occur with IPH is myocardial injury, which can result in death (Frank et al., 1997). Hypothermia causes patients to shiver during the postoperative period and can be quite uncomfortable. This thermal discomfort is stressful to the body and causes elevated blood pressure, increased heart rate and a release of plasma catecholamines (Miller et al., 2015). These factors

more than likely contribute to cardiac compromise in hypothermic patients. Frank et al. (1997) conducted a randomized clinical trial to examine routine thermal care patients and supplemental warming along with routine thermal care. All 300 subjects recruited for the study had known coronary artery disease or a known increased risk. Perioperative morbid cardiac events occurred far less frequently in the normothermic group than the hypothermic group. A 55% reduction in incidence of cardiac events was found in normothermic patients (Frank et al.). Few studies examining this topic were found in the literature.

Coagulation is greatly impaired with mild hypothermia. The main mechanism appears to be related to the alteration that occurs to platelets. Promotion of platelet margination due to increasing hematocrit, changing of the shape of platelets, slower blood flow rate, and an increase in the expression of adhesion molecules are directly linked to a hypothermic state (Van Poucke, Stevens, Marcus, & Lance, 2014). Platelet aggregation is also found to be higher when a patient experiences hypothermia. Blood is a two-phase liquid with a solid-liquid suspension and directly effects viscosity. Viscosity is temperature dependent; hypothermia increases viscosity and leads to increased platelet aggregation. (Van Poucke et al.). One of the more important functions of the body is the ability to clot and preserve blood volume and hypothermia can directly affect that protective mechanism.

Another essential mechanism of the body that is disturbed by hypothermia is drug metabolism. While a majority of drugs have little to no reports on metabolism and pharmacodynamics related to hypothermia, some important medications used in the anesthesia-setting do. One of those affected by hypothermic conditions is propofol. For

patients that are 3° C. hypothermic, plasma concentrations of propofol are roughly 30% greater than when patients are at the normal temperature (Miller et al., 2015). Volatile agents, such as sevoflurane and desflurane, are also altered by hypothermia. Minimum alveolar concentration, a means of measuring the depth of anesthesia during surgery, is reduced by 5% for every ° C. below 36° C (Miller et al.). The effects can extend anesthesia and prolong awakening, extend post anesthetic recovery time and increase perioperative costs (Miller et al.)

Wound infections are among the most common complications during surgery and are compounded by IPH. Due to hypothermic conditions, immune function is impaired as well as decreased wound oxygen delivery by vasoconstriction (Miller et al., 2015). Neutrophils are synthesized in the presence of oxygen. Bacterial destruction caused by free radicals is completely dependent on tissue perfusion (Flores-Maldonado, Medina-Escobedo, Rios-Rodriguez, & Fernandez-Dominguez, 2001). The peripheral vasoconstriction of the patient who is hypothermic leads to inadequate nutrient and oxygen supply and increases the frequency of surgical would infection (Silva & Peniche, 2014). Fever is a protective mechanism for infection and hypothermia directly opposes this response. The thermoregulation automaticity of the body is lost during general anesthesia and will not raise core temperature (Silva & Peniche). This requires the patient to receive an external source of heating to remain normothermic. Based on this information, it is extremely important for anesthesia providers to achieve normothermia in patients undergoing anesthesia in order to minimize the adverse effects of hypothermia.

With all of the potential complications that are associated with hypothermia, it is important for providers to do what is best for the patient and continue to maintain normothermia throughout the perioperative period. However, mild hypothermia can have some benefits for specific patients when it is utilized and performed with precision and vigilance. For example: patients suffering from brain trauma show improved outcomes; myocardial infarction can be mitigated with hypothermic ischemia protection; and acute malignant hyperthermia is more resistant to triggering when patients are hypothermic (Miller et al., 2015). While beneficial to these specific patient populations, mild hypothermia should not be applied to other populations (Callaway et al., 2014). Therapeutic hypothermia can benefit those who require it, but not every patient should be allowed to become hypothermic by anesthesia providers (Callaway et al.). Extremely close monitoring guidelines and treatment protocols are necessary in order to allow a patient to become hypothermic.

Forced Air Warming Technique to Prevent IPH and Preoperative Use

There are various strategies to manage IPH, one of which is the forced-air warming unit. There are many different brands and types of forced-air warming units, which are similar in structure and function. A power unit generates warmed air and blows the air through a hose onto a patient-specific blanket that is directly in contact with the patient (Xuelei, 2013). The forced-air warmers typically have three different temperature settings; different blanket sizes and specific body area blankets are available. These types of devices have been shown to decrease hypothermia in patients undergoing surgery (Xuelei, 2013).

Forced-air warming units are used during the intraoperative period quite extensively and have become extensively used in the operating room (Kurz, 2008). The prevention of hypothermia using forced-air warming during the intraoperative period has been supported throughout many studies over the last two decades. A recent meta-analysis by Nieh & Su (2016) aimed to assess the use of forced-air warming to prevent perioperative hypothermia and patient thermal comfort versus several other warming modalities. At the time of the meta-analysis, there were several studies with differing opinions on warming, however, no recent reviews conducted to verify the effectiveness of various warming systems (Nieh & Su). The researchers were able to support what many practitioners in the field of surgery and anesthesia previously knew. The review included a total of 29 trials (N =1875), seven of which (n = 502) were specifically related to patient thermal comfort. They found forced-air warming to be effective in combating hypothermia; it was more effective than passive insulation and circulating-water mattresses. However, there were no statistical differences in effectiveness between forced-air warming versus circulating water garment, radiating warming system, or resistive heating blanket. Two of the trials analyzed compared upper and lower body forced-air warming. Two hundred and ten patients who underwent surgery were found to have a standard mean difference of 0.371° C, indicating there was almost no temperature disparity between top half of the body versus bottom half when using forced-air warming. Seven trials compared thermal comfort of patients using the various warming techniques. A total of 502 patients undergoing surgery were assessed and using a random-effects model, the forest plot showed an odds ratio of 2.919 indicating the forced-air warming improved thermal comfort more effectively than passive insulation,

resistive heating blanket and radiating warming system. (Nieh & Su). It is apparent why the forced-air warming units are the most widely used intervention in preventing hypothermia during the intraoperative period. There are many studies proving its efficacy over several years and this recent meta-analysis validates its' routine use in surgical patients.

Currently, there are many companies with forced-air warming products available for institutions to utilize. The company 3M has two of the most commonly used forced-air warming systems used by many institutions today (2011). They offer the Bair Paws™ and Bair Hugger™ systems that are designed to combat hypothermia during the preoperative, intraoperative, and postoperative period. The Bair Paws™ system is an all-in-one gown that is worn by the patient and acts as the warming unit during the perioperative period. No additional warming blanket is needed and the patient is able to control the temperature of the air flow using a dial controller. The Bair Hugger™ system is the original forced-air unit system that was introduced in 1987. It requires a patient specific warming blanket and there are 3 temperature settings of low (32° C), medium (38° C), and high (43° C). The latest 3M brochure states that the Bair Hugger™ system has warmed over 135 million patients and 130,000 units are utilized today (3M). At the time of the most recent 3M brochure, between both forced-air warming systems, a total of seven warming units and a total of 25 different warming blankets are available. The blankets vary in size, positioning, and access points to provide optimal warming area depending on surgical procedure.

There are some potential issues with forced-air warming systems despite the numerous benefits. Two potential complications that are associated with forced-air

warming during the perioperative period are thermal burns to skin and surgical site infections. Thermal burns are extremely rare when using the forced-air warming unit appropriately and to manufacturer standards. According to a case report from South Korea, a 37-year-old patient underwent spinal anesthesia for arthroscopic knee surgery (Chung, Lee, Oh, Choi & Cho, 2012). No events noted during the procedure, but the patient complained of being cold in the post anesthesia care unit. The staff proceeded to initiate the forced-air warming unit directly under a cotton blanket instead of using the manufacturer blankets that need to be used with the unit to be effective. After 30 minutes of warming, the patient acquired a 5 cm x 10 cm bullae like lesion on her lower abdomen. A patient who is anesthetized or sedated, may not be able to communicate pain from thermal burns or direct heat (Chung et al.).

Surgical site infections are also considered a potential complication that could result from forced-air warming. However, a review conducted by Kellam, Dieckmann and Austin (2013) found no causal link between surgical site infections and forced air warming This literature review utilized 15 studies to assess whether forced-air warming units had a direct or indirect impact on surgical site infections. The direct method was to follow patients who were warmed intraoperatively with forced-air warming and whether this correlated to increased likelihood of surgical site infections. There were three indirect methods: examine the intake, inside, and output hoses of forced-air warming units or air emitted for bacteria or particles that might harbor bacteria; evaluate bacterial counts near or on patients, volunteers, or manikins in the operating room; and examine unwanted airflow disturbances in the OR caused by forced-air warming. The evidence reviewed did not conclusively indicate that forced-air warming was a cause of surgical

site infections. Direct methods showed that two of the three studies had a total of 47 patients undergoing surgery; none documented postoperative surgical site infection. As far as indirect methods, five of the six studies found forced-air warmers to harbor or expel bacteria related to low filtration rates and poor cleaning practices. When addressing the second indirect method, five studies all found that there was zero to slight increases in airborne or on patient, volunteer and manikin bacterial contamination when using forced-air warming compared to when the patient was assisted onto the operating room table. The final indirect method demonstrated that forced-air warming was likely to cause unwanted airflow disturbances. These studies were not conducted during actual surgical procedures, but controlled realistic simulations. However, there was no link found between unwanted airflow disturbances and surgical site infections (Kellam et al).

Clinical Practice Guideline related to Forced-Air Warming

In April 2008, the National Collaborating Centre for Nursing and Supportive Care commissioned by the National Institute for Health and Clinical Excellence (The management of inadvertent perioperative hypothermia in adults, 2008) developed a clinical practice guideline for the management of inadvertent perioperative hypothermia in adults. The 567-page document detailed principles of practice, aims of the guideline, recommendation, physiology, detection and monitoring, prevention, treatment, statistics, cost-effectiveness and implementation. Many doctors, advanced practice nurses, nurses, educators and others helped to develop this best practice guideline, as illustrated in Figure 1 on the next page.

The algorithm shows that forced air warming should be implemented prior to or at the induction of anesthesia and maintained throughout the perioperative period, as

necessary for patient normothermia. There is no standard or guideline for preoperative forced air warming, supporting the need for this systematic review.

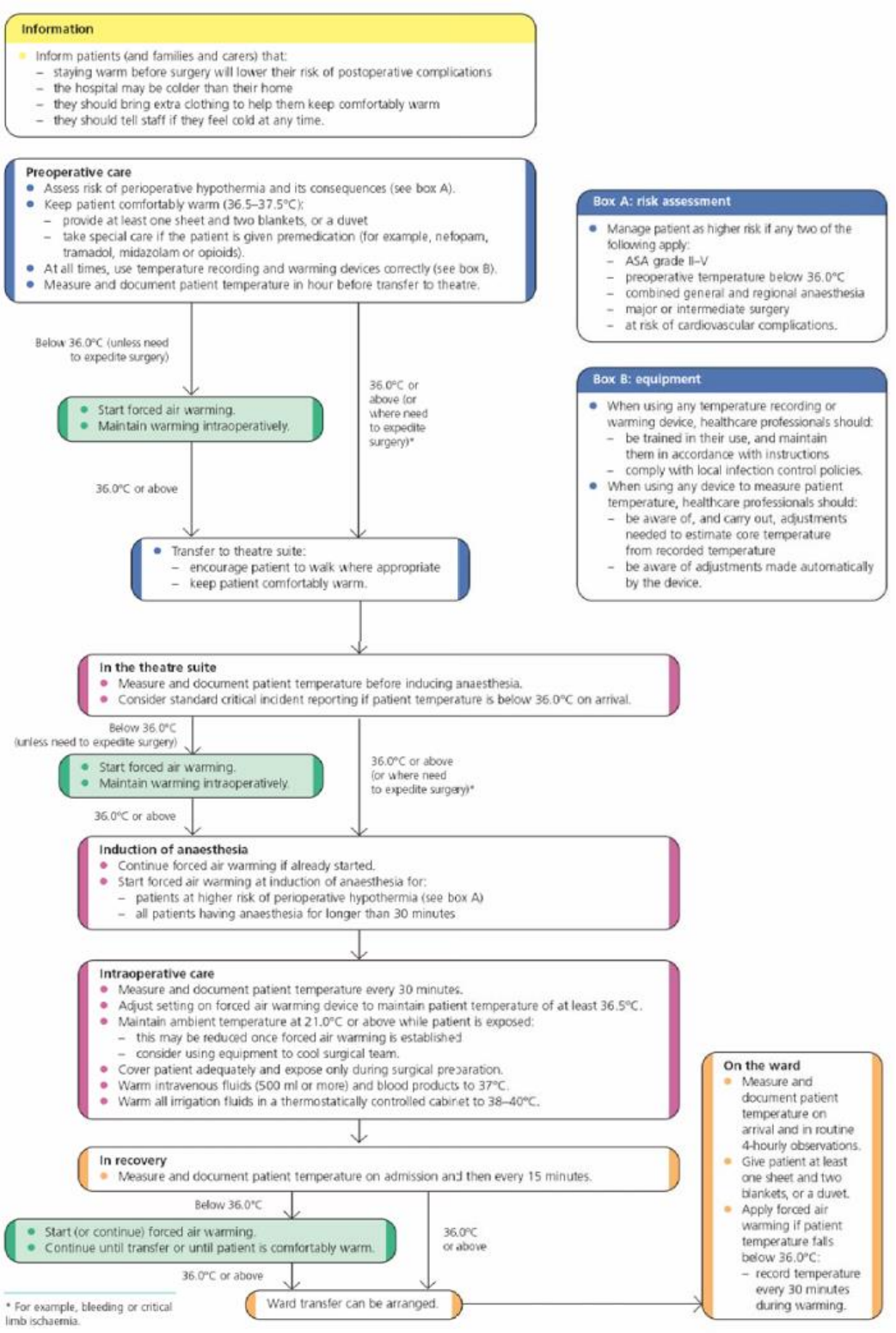


Figure 1. *The inadvertent perioperative hypothermia (IPH) patient algorithm*

Research related to Preoperative Forced-Air Warming

The literature related to forced-air warming is plentiful as shown above. Conversely, there is much less literature pertaining to preoperative forced-air warming and its' use in preventing IPH. There are some studies and systematic reviews, but many focus on several different methods of warming rather than just forced-air warming. As discussed above, forced-air warming appears to have many benefits that other warming systems do not. Many of the randomized control trials reveal that preoperative warming can be beneficial, but disparity in results is also evident. Due to this disparity, further appraisal of the literature is warranted and thus the basis for this systematic review.

Next, the theoretical framework will be discussed.

Theoretical Framework

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) was developed to assess and improve the quality of reporting for systematic reviews and meta-analyses. A 27-item checklist and a four-phase flow diagram are the two major aspects of the PRISMA Statement that are utilized for reporting and analysis of evidence-based research articles (Moher, Liberati, Altman, & The PRISMA Group, 2009). Seven major heading are present on the checklist, which is illustrated in Table 1 on the next page. The checklist and flow diagram allow researchers to review and evaluate articles pertaining to a particular topic and present the information in a precise and consistent manner. Many health care professionals employ systematic reviews today and PRISMA provides a consistent method for reporting these findings.

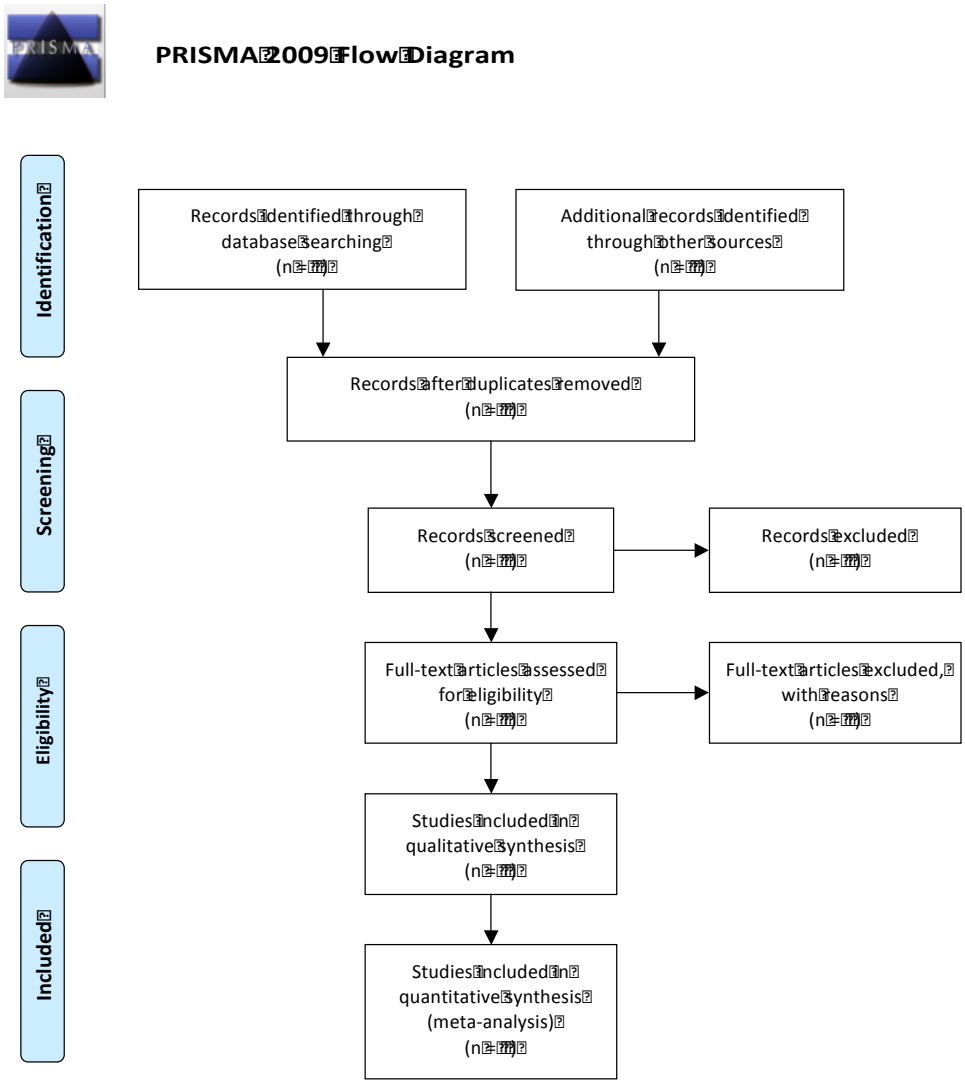
Table 1

PRISMA Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	

The PRISMA statement is a relatively new framework that has adapted to the always-evolving world of healthcare. In 1996, the QUOROM, Quality of Reporting of Meta-Analyses, was developed by an international team to address the less than ideal reporting of meta-analyses (Moher et al., 2009). The quality of the information and the presentation were below the appropriate standard and necessitated revisions. As systematic reviews and meta-analyses became more prevalent, the criteria for examining the research needed to be updated. That is when PRISMA came to fruition, as a panel of 29 review authors, methodologists, clinicians, medical editors, and consumers held a three-day meeting in Ottawa, Canada (Moher et al., 2009). The Preferred Reporting Items for Systematic Reviews and Meta-Analyses focuses on randomized trials and is a framework that will be employed for this systematic review.

The PRISMA flow diagram is used to display how the researcher selected the articles appraised for the systematic review. The flow diagram can be seen on the next page in Figure 2. The number of articles diminishes based on identification, screening, eligibility and inclusion into the review based on the researcher's criteria for selection.



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit www.prisma-statement.org.

Figure 2. PRISMA Flow Diagram

The Critical Appraisal Skills Programme, or CASP, checklist will be used to critically appraise the randomized control trials included in this systematic review as illustrated below.

Table 2

CASP Checklist for Randomized Controlled Trials

Question	*Yes*	*Can't Tell*	*No*
Did the trial address a clearly focused issue?			
Was the assignment of patients to treatments randomized?			
Were all of the patients who entered the trial properly accounted for at its conclusion?			
Were patients, health workers and study personnel blinded?			
Were the groups similar at the start of the trial?			
Aside from the experimental intervention, were the groups treated equally?			
How large was the treatment effect?			
How precise was the estimate of the treatment effect?			
Can the results be applied in your context? (Or to the local population?)			
Were all clinically important outcomes considered?			
Are the benefits worth the harms and costs?			

(Singh, 2013)

This program was one of the first methodologies for critical appraisal developed by Dr. Amanda Burls in Oxford, England (Singh, 2013). The CASP approach focuses on 3 main topics to address the articles found: Find, Appraise, and Act. Evidence found, a subheading of the Find topic, is further explained by addressing various types of sources that could be used and the limitations associated with each (Singh). The Appraise section stresses reviewing the reliability of scientific articles and whether biases are present in the studies. Validity of the studies, importance of the results found, and the results application to the research is emphasized and the correct methods of critically reading the articles also are found in this section (Singh). The final aspect of the CASP sections is Act. The extent to which the findings of the studies relate to the situation of the research, practical issues that affect the study, and how applicable the local context of the studies is explored (Singh). These three separated sections allow the user to easily identify the most efficient way to tackle the critical appraisal of the articles pertaining to the topic of interest. CASP will be used to evaluate each individual study initially then be used to assess across all studies for data synthesis.

There are several different checklists available based on the types of studies being critically appraised such as systematic reviews, randomized controlled trials, cohort studies, etc. For this particular systematic review, randomized controlled were analyzed and the Randomized Controlled Trials checklist will be utilized. It consists of 11 questions to approach the articles in a structured manner to find evidence and improve the quality of the screening process (Singh, 2013). The checklists are quite easy to follow and for the novice researcher, which is why the CASP appraisal tool has been chosen to critically appraise the articles found in this systematic review.

The Critical Appraisal for Summaries of Evidence or CASE tool modified for this particular systematic review will be used to assess across studies. The authors of this tool (Foster & Shurtz, 2013) developed it in order to assess the evidence found in each of the studies in a systematic fashion. The topics found in the worksheet include topic, methods, content and application to practice. The 10-question worksheet, illustrated in Table 3 on the next page, can be answered with yes, no, or not completely answers based on several topics. The original tool has been modified for this systematic review to make it as pertinent and appropriate as possible.

Next, the method of the systematic review will be discussed.

Table 3

CASE Worksheet

Critical Appraisal for Summaries of Evidence (CASE) Worksheet **Numbers in evaluation correspond with those assigned to articles in data extrapolation chart**	
Questions	**Evaluation**
Summary Topic	
Is the summary specific in scope and application?	Yes- Not completely- No-
Summary Methods	
Is the authorship of the summary transparent?	Yes- Not completely- No-
Are the reviewer(s)/editor(s) of the summary transparent?	Yes- Not completely- No-
Are the research methods transparent and comprehensive?	Yes- Not completely- No-
Is the evidence grading system transparent and translatable?	Yes- Not completely- No-
Summary Content	
Are the recommendations clear?	Yes- Not completely- No-
Are the recommendations appropriately cited?	Yes- Not completely- No-
Are the recommendations current?	Yes- Not completely- No-
Is the summary unbiased?	Yes- Not completely- No-
Summary Application	
Can this summary be applied to your patient(s)?	Yes- Not completely- No-

(Foster & Shurtz, 2013)

Method

Purpose of Study

The purpose of this project was to complete a systematic review related to prevention of inadvertent perioperative hypothermia (IPH) in adult patients undergoing general or neuraxial anesthesia using preoperative forced-air warming systems. Using the PICO format, the question was: In adults undergoing general anesthesia, what is the impact on patient temperature with the addition of preoperative forced-air warming to intraoperative warming, compared with intraoperative warming alone, on incidence of inadvertent perioperative hypothermia and perioperative temperature measurement?

The main outcomes that were assessed in this study included temperature readings during the intraoperative and immediate postoperative periods. The adverse effects were not being addressed because they are patient specific and can occur independently for each patient.

Inclusion and Exclusion Criteria

The inclusion criteria included randomized controlled trials, patients older than 18 undergoing neuraxial or general anesthesia, preoperative forced-air warming units for thermoregulation, studies assessing intraoperative as well as postoperative temperature monitoring and articles in English.

The exclusion criteria included surgical procedures in pediatric populations due to differences in thermoregulation, studies other than randomized controlled trials, prewarming methods other than forced-air warming, studies not assessing temperature monitoring, studies greater than ten years old, and articles not in English.

Data Collection and Synthesis

A table developed from an article by Fineout-Overholt, Melnyk, Stilwell & Williamson (2010) will be utilized to collect and organize the information (Table 2). Each column has a heading to allow for description of the information found in that column. One issue that can arise is the use of differing terminology across studies. For this reason, keeping data in the table consistent by using simple, inclusive terminology will allow for a more concise heading for each section (Fineout-Overholt et al.). The table format to be used for all studies is shown below (Table 4).

Table 4

Data Collection Template

Setting/ Sample	Method/ Design	Time of preoperative warming and device, Intraoperative temperature device and site	Temperature setting of FAW	Patient intraoperative temperature	Patient postoperative temperature	Limitations

To critically appraise across the studies, several factors will be assessed. These factors include: number of participants, time period of preoperative warming, temperature setting of forced-air warming unit, patient intraoperative temperature, intraoperative temperature measuring device and the site where temperature is being assessed, postoperative patient temperature, and limitations. Comparing these across all studies will help to assess the results and draw conclusions about the data from each individual study and as a collection.

Results

Based on the inclusion criteria, a total of six studies were included in this systematic review. The PRISMA flow sheet was used to show the breakdown of search results below (Figure 3). Each study was analyzed and pertinent information was inputted into separate tables found in Appendix A.

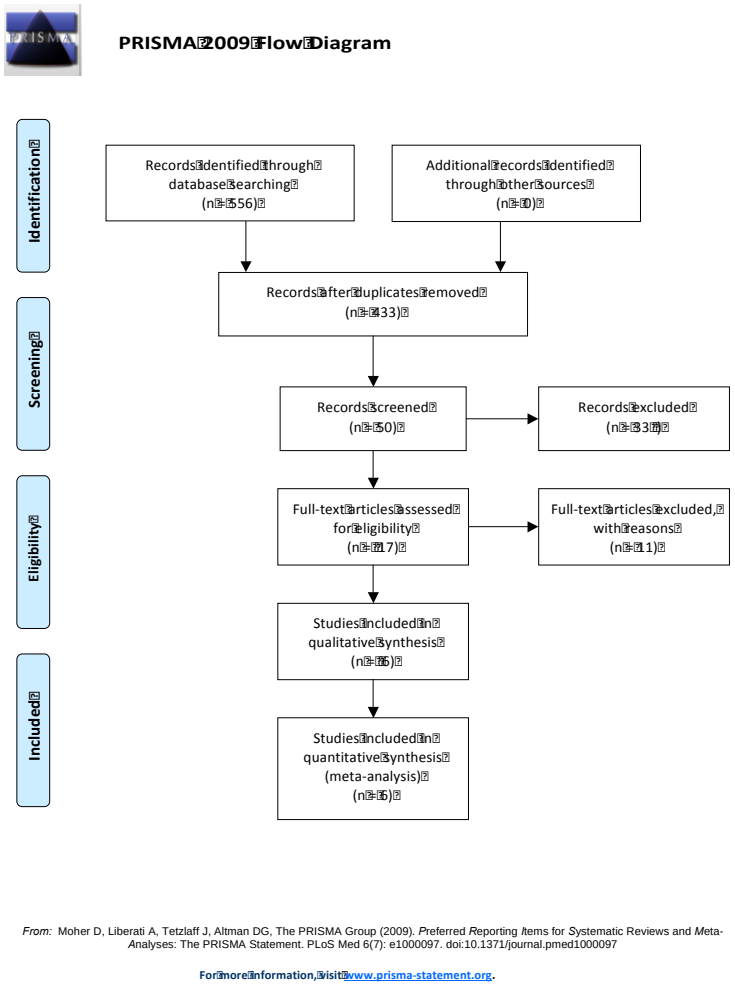


Figure 3. PRISMA Flow Diagram for Systematic Review

A study by Andrzejowski et al. (2008; Appendix A1) assessed 68 patients undergoing spinal surgery under general anesthesia, a mix of total intravenous anesthesia and sevoflurane to maintain anesthetic requirements. The authors calculated a sample size of 35 for each group would provide a power of 0.8 and significance level of 0.05. A computer-generated randomization technique was used to divide the two groups: prewarmed versus non-prewarmed. After surgical cancellations, 31 patients were in the prewarmed group and 37 patients were in the non-prewarmed group. The Bair Paws® system was used at a temperature of 38° C for approximately 60 minutes in the preoperative period. No other warming techniques were used. Those in the non-prewarmed group were warmed during the intraoperative period. Temperatures were recorded by esophageal thermometer every 20 minutes during the intraoperative period and into the postoperative period. A significantly smaller decrease in core temperature was found in the prewarmed group at the 40, 60, and 80 minutes intervals. Also, the mean core temperature of the prewarmed group was greater than the control group ($P < 0.005$). A larger percentage of patients ($P < 0.05$) remained normothermic throughout the procedure in the prewarmed group compared with the control group, 68% and 43% respectively.

The study was critically appraised using the CASP tool (Appendix B1). A total of 76 adult patients were randomized into two groups to evaluate the effect of prewarming on post-induction core temperatures and the incidence of IPH. The groups were found to be similar and received similar treatments besides the experimental intervention. The data showed that at intraoperative time frames of 40, 60, and 80 minutes, the prewarmed group was significantly ($p < 0.05$) warmer than the control

group and a larger portion of the patients remained normothermic throughout surgery in the prewarmed group. Preoperative forced-air warming of patients was found to be effective in combating IPH.

The next study by Horn et al. (2012; Appendix A2) aimed to evaluate the use of preoperative forced-air warming at different durations to prevent IPH. A total of 200 patients were randomly assigned to one of four treatment groups: passive insulation (no warming); 10 minutes; 20 minutes; or 30 minutes. The authors calculated that for an expected treatment effect of 0.5° C on postoperative temperature, a sample size of 200 for all groups would provide a power of 0.8 and significance level of 0.05. During the preoperative period, patients were warmed for the set amount of time determined by their random group at a temperature setting of 44° C using the Level 1 Equator® warming system. Patients were kept warm during surgery using cotton blankets, unless the patient's temperature dropped below 36° C. At that point, the patient would be warmed with a forced-air warming unit. Tympanic membrane thermometers were used by to record patient temperatures every 15 minutes during the perioperative period. At the start of PACU, 30 out of 55 (69%) were hypothermic. Only seven of 52 (13%), three of 43 (7%), and three of 50 (6%) in the 10-minute, 20-minute and 30 minute prewarming groups respectively were found to be hypothermic ($p < 0.00001$). No statistical significance was found between treatment groups ($p = 0.54$). The authors inferred that only 10 or 20 minutes of prewarming before general anesthesia can greatly reduce and mostly prevent IPH.

The critical appraisal of this study by Horn et al. (2012; Appendix B2) was completed with CASP. A total of 200 adults undergoing general anesthesia for a variety

of surgical procedures were randomized into one of four groups with either no warming, 10 minutes, 20 minutes or 30 minutes of preoperative forced-air warming. There were no differences found between groups and all treatments were maintained throughout all groups besides the degree of preoperative warming. Statistical significance was demonstrated between the temperatures of prewarmed groups versus the control group on arrival to PACU ($p < 0.05$). The authors suggested warming for 10 to 20 minutes during the preoperative period to help counteract IPH in the intraoperative and postoperative periods. This particular study supports the focus of this systematic review.

The third study by Nicholson (2013; Appendix A3) compared the effects of two different warming methods in the preoperative setting on perioperative temperatures of adult patients undergoing general anesthesia for colorectal surgery. For a desired power of 0.8 and a significance level of 0.05, the author calculated a sample size of 44 patients. A total of 66 patients made up the sample. Randomization placed patients into one of two groups: preoperative use of no active forced-air warming and just the use of cotton blankets versus a forced-air warming unit for greater than a 30 minute period during the preoperative period. Different means of temperature methods were used based on anesthesia providers' preference. All patients received intraoperative forced-air warming. There was no statistical difference ($p = 0.05$) based on mean PACU admission temperatures between the no prewarming group and the prewarmed group. The authors noted that these findings differ from other published studies. All 34 patients (100%) in the prewarmed group had temperature greater than 36° C on arrival to PACU as compared to 32 patients (91%) in the no prewarming group. Not all patients received other means of warming during the intraoperative period such as warmed irrigation and

IV fluids, warmed humidified gases. Also, intraoperative warming occurred before induction of general anesthesia for all patients using forced-air warming and the amount of time of this warming was not recorded.

Critical appraisal of Nicholson (2013; Appendix B3) opposed the results portrayed in the first two studies. Sixty-six patients were randomized to either a control group or a group that was warmed for at least 30 minutes, but not with a set time limit. Groups were similar at the start of the trial, but intraoperative interventions varied between groups and even within groups. Thermometer sites and other warming measures were not consistent throughout the trial. Results of the study showed no statistical difference in postoperative temperatures between the two groups, but these results may be skewed related to inconsistent treatment of patients.

The next study assessed was conducted by Horn et al. (2016; Appendix A4) and evaluated the effects of active forced-air warming before and/or after initiation of epidural analgesia during general anesthesia to prevent IPH. Ninety-nine adult patients scheduled for major abdominal surgery were randomized into three different groups: “no warming” group received only intraoperative warming and no preoperative warming; “warming after epidural” group received active preoperative forced-air warming for 15 minutes after the epidural was placed; and “warming before and after” group received active preoperative forced-air warming for 15 minutes before and after the epidural was placed. The authors calculated a sample size of 99 patients would provide a power of 0.8 and a significance level of 0.05. Once premedication, intravenous catheter placement and warmed fluids were administered, patients underwent similar procedures for epidural placement, with the warming technique as the only difference. Tympanic

membrane thermometers were used for core temperature measurements that were consistent throughout all groups. All patients received intraoperative forced-air warming at 44° C using Level 1 Equator® warming system. Results were as follows: 72% (n = 71) of patients in the "no warming" group were hypothermic on arrival to ICU; only 6% (n = 6) of the "warming after epidural" group was hypothermic; and 0% of patients in the "warming before and after epidural" group were hypothermic on arrival to ICU ($p < 0.05$). The authors stated that preoperative forced-air warming before and after epidural placement for general anesthetic procedures was sufficient to prevent hypothermia in all patients.

Horn et al. (2016; Appendix B4) was also critically appraised using the CASP worksheet. Ninety-nine patients were randomized using dice into one of three groups with no prewarming, prewarming after epidural placement or prewarming before and after epidural placement. No deviation from a normal distribution regarding patient characteristics in each group was noted and all groups received the same anesthetic plan and intraoperative warming measures throughout. The results showed that forced-air warming prior to and after epidural placement was sufficient to prevent hypothermia in patients undergoing major abdominal surgery. The study and its results are pertinent to this systematic review.

Jo, Chang, Kim, Lee & Kwak (2015; Appendix A6) evaluated 49 elderly patients undergoing spinal anesthesia for transurethral resection of the prostate surgery. Patients were randomly assigned to either the control or intervention group. The intervention group received preoperative forced-air warming for 20 minutes prior to spinal administration. Core temperatures were measured every 15 minutes by an infrared

tympanic membrane thermometer. The authors calculated that 23 patients in each group would provide a power of 0.8 and significance level of 0.05. Twenty-five patients were in the intervention group, while 24 patients were in the control group due to a conversion to general anesthesia for one patient. No significant differences were observed between groups including sensory block level, volume of irrigation fluid, or total amount of IV fluids intraoperatively. Other than the forced-air warming intervention, all patients received pre-hydration, similar ambient temperatures, intraoperative warming with a circulating water mattress at 36° C and spinal technique and appropriate dosing based on patient height. There was no statistically significant difference between the groups in terms of core temperature measurement upon arrival to the recovery room ($p = 0.259$). However, there was statistical significance ($p = 0.019$) in the severity of hypothermia between groups. While no patients in the prewarmed group showed moderate or profound hypothermia, in the control group, patients were found to be moderately hypothermic (21%; $n = 5$) and profoundly hypothermic (13%; $n = 3$).

The next critically appraised article by Jo et al. (2015, Appendix B5) was also an important inclusion into this systematic review. A sample of elderly male adult patients was randomized into two groups of either no prewarming or prewarming prior to spinal anesthesia. 20 minutes of prewarming was found to not totally combat hypothermia ($p = 0.259$), but was found to significantly decrease the severity of hypothermia ($p = 0.019$). These results can be applied to this systematic review and help to provide guidance on the use of preoperative forced-air warming to combat IPH.

The final study by Fettes et al. (2013; Appendix A6) studied adult patients undergoing general anesthesia for a variety of procedures. The patients were randomly

assigned to either the intervention or control group. One hundred and twenty-eight patients, 54 in the intervention group and 74 in the control group, were found to have similar characteristics at the start of the study. Patients in the intervention group were warmed in the preoperative area for roughly an hour with a forced-air warming blanket at 37.8° C, while patients in the control group were only given a cotton blanket. All patients received the same intraoperative warming measures including forced-air warming, warmed IV fluids and warmed irrigation fluids. Temporal artery-scanning monitors were used throughout the perioperative period. The authors calculated a sample size of 64 patients for each group would provide a power of 0.8 and a significance level of 0.05. There was no statistically significant difference between the intervention and control groups ($p = 0.508$). Patients in the intervention group were found to have a mean core temperature of 0.1° C greater than the mean core temperature of the control group on arrival to the PACU. There were limitations to this study including unequal distribution of participants, untimed preoperative warming time, and lack of hypothermia in all patients.

The critical appraisal of Fettes et al. (2013, Appendix B6) using CASP had differing results from some of the other studies assessed in this systematic review. A total of 128 adult patients undergoing multiple types of surgeries were randomized based on medical record numbers into either a prewarmed group for an unspecified time (~ 60 minutes) or a standard no warming group. No statistical difference was found ($p = 0.508$) between groups regarding postoperative temperatures. Many other intraoperative warming techniques, unbalanced participants and overall lack of hypothermia may have affected the results of the study. This study and its information can still be applied to this

systematic review though its results were not consistent with some of the studies with stronger designs.

Prior to conducting the cross study analysis, all studies were individually analyzed using the CASE worksheet (Appendix C1-6). Results from the individual CASE worksheets were compiled into a single table to accurately compare the studies alongside each other (Appendix D). The studies with a majority of "yes" scores are considered to be high quality and those studies with numerous "not completely" or "no" scores are considered to be lacking in key areas. The numbering of the studies was maintained throughout all tables and correlate to the information in the table. Nicholson (2013; Study 3) was scored lower using CASE: the authorship was not completely transparent, the recommendations were not clear and the summary was not unbiased. Based on this assessment, and those noted in using the CASP tool, which showed uneven treatment across groups regarding intraoperative warming methods and differences in temperature measuring devices, the Nicholson (2013) study is identified as having significant methodological limitations. The other study conducted by Fettes et al. (2013; Study 6) also scored poorly on the CASE worksheet. The transparency throughout was found to be poor and the recommendations were not completely clear. The summary appeared biased related to the citation of articles that only supported similar results to this particular study and not citing articles with differing results. Based on these findings, the results cannot completely be applied to the patient population. The CASP tool showed that this study by Fettes et al. (2013) had a large difference in its control group and experimental group as far as number of participants and other extensive intraoperative warming methods could have affected their results. Both of

these studies had significant flaws and the results showed no changes in patients who received preoperative forced-air warming as compared to those patients who did not receive prewarming treatment The other studies by Andrzejowski et al. (2008; Study 1), Horn et al. (2012; Study 2), Horn et al. (2016; Study 4), and Jo et al. (2015; Study 5) were found to have the most "yes" scores and were identified as the highest quality studies in this systematic review. The results of these studies all showed that forced-air warming during the preoperative period was able to prevent IPH and its effects throughout the perioperative period.

Next, the summary and conclusions will be addressed.

Summary and Conclusions

A systematic review was conducted to assess the results in preventing inadvertent perioperative hypothermia (IPH) in adult patients undergoing general or neuraxial anesthesia using forced-air warming systems, specifically during the preoperative period, as compared to intraoperative warming techniques alone. The endpoint of perioperative temperature measurements in patients receiving preoperative forced-air warming versus perioperative temperature measurements in patients receiving standard forced-air warming was analyzed. Academic Search Complete, CINAHL Plus and Medline databases were searched to find articles pertaining to the proposed topic. A comprehensive literature review highlighted the impact that IPH can have on patients undergoing surgical procedures and the detrimental consequences that can occur from it. An abundance of literature on hypothermia and how to manage it could be found, but a focus on the use preoperative forced-air warming has been studied less than originally expected. Many clinical practice guidelines have been developed, such as the one referenced earlier by National Collaborating Centre for Nursing and Supportive Care commissioned by the National Institute for Health and Clinical Excellence. However, many of these guidelines do not stress the use or importance that preoperative forced-air warming could have on prevention of IPH. The need for this systematic review was apparent upon review of the literature.

After developing inclusion and exclusion criteria, a total of six studies were identified and the PRISMA checklist and flow diagram were utilized to assess those studies. Studies were screened to ensure proper components to fit the systematic review. Two critical appraisal tools were also utilized to analyze each study. The CASP tool was

employed to analyze each study and approach the articles in a structured manner to find evidence and improve quality of the screening process. For the appraisal of the summaries of each of the six studies, the CASE worksheet was used to gauge transparency, scope, recommendations, and bias. The CASE worksheet was then used to complete a cross study analysis to identify the studies' quality.

As with all studies, there were some limitations to this systematic review. Only six studies met the inclusion criteria for this study; clearly, further research is indicated. Also, looking at intraoperative and postoperative temperatures without regard to preoperative temperatures could have potentially had some effect on patient temperatures. The use of other intraoperative warming methods (warmed IV fluids, warmed irrigation fluids, etc.) by some studies was employed, while others strictly employed forced-air warming. The timing of preoperative forced-air warming was also not consistent throughout all studies and could be considered a limitation. An argument also could be made that the variations in procedure types have quite different thermodynamic implications and could have an impact on results. A limitation of this systematic review and its process were that only three databases were used in searching for articles. The use of more databases for the article search could have potentially impacted the number of studies meeting the inclusion criteria.

Each of these six studies were examined extensively and appraised using the previously mentioned tools. A majority of the studies Andrzejowski et al. (2008; Appendix A1), Horn et al. (2012; Appendix A2), Horn et al. (2016; Appendix A4), and Jo et al. (2015; Appendix A5) showed that preoperative forced-air warming either completely prohibited hypothermia or decreased the severity to which hypothermia was

measured versus the control groups. These four randomized controlled trials were also found to be of high quality. Two other studies Nicholson (2013; Appendix A3) and Fettes et al. (2013; Appendix A6) were examined and results revealed no significant difference between prewarmed and non-prewarmed groups. However, these studies were found have to have significant methodological limitations that could have effected results.

In summary, the majority of studies included in this systematic review, and the four methodologically strongest studies supported that preoperative forced-air warming prior to general or neuraxial anesthesia can address or mitigate IPH throughout the preoperative period.

Next, the recommendations and implications for advanced practice nursing will be discussed.

Recommendations and Implications for Advanced Nursing Practice

Hypothermia occurs frequently in the operating room and can cause severe adverse events such as cardiac complications, coagulopathies, metabolic effects and increased risk for infection. It is clear that for the advanced practice nurse, especially the CRNA, regulation of body temperature is critically important to the patient's well being. Anesthetics promote loss of body heat in addition to an already cooler operating room environment. These factors make it difficult to maintain patient normothermia during the perioperative period. The Certified Registered Nurse Anesthetist should utilize evidenced-based practices to minimize IPH.

One way that hypothermia can be minimized is the use of forced-air warming. Many practitioners utilize forced-air warming during the intraoperative period to warm patients to acceptable temperatures. Forced-air warming is less widely used in the preoperative setting. Four of the six randomized controlled trials critically analyzed in this systematic review demonstrated that preoperative forced-air warming can substantially reduce the incidence of hypothermia in the perioperative setting. This practice can abate the potential effects of hypothermia and keep the surgical patient safer.

For the CRNA, the act of initiating preoperative warming could be a challenge. It would be important to collaborate with the preoperative nurses and staff to implement a policy of forced-air preoperative warming. Certified Registered Nurse Anesthetists care for one patient at a time, start to finish. Between each patient case, the CRNA has only a limited amount of time to prepare for the next patient. In many settings, anesthesiologists and preoperative nurses complete a comprehensive preoperative

assessment and the CRNA usually reviews this information. There is more substantial time spent by preoperative nurses with the patient in the preoperative period than anesthesia providers and this provides nurses the opportunity to provide warming at an earlier time. The preoperative nurses could ensure adequate warming times during their assessment and could begin preoperative warming at this time. Based on these points, the role of the CRNA would be to continue warming into the operating room and to also promote policy changes to fully implement preoperative forced-air warming. Becoming a member of committees that develop policies or attending meetings that discuss potential policy needs could help to initiate the production of policies regarding forced-air warming. The CRNA can also work with nursing and anesthesiologists to discuss and develop the policy that works best for patients and caregivers.

Several companies have gowns with a forced-air warming mechanism built right in. It would be simple to have the patient put on this specialty gown like the cotton gowns that are already used. The specialty gown could be used in many areas. The CRNA could utilize this for preoperative warming and continue its use in the intraoperative period. With that being said, preoperative areas would need to purchase a sufficient amount of forced-air warming units and could become costly depending on the size of the unit. Also, the specialty blankets and warmers for patients could be costly depending on the number of patients a facility operates on each day. The CRNA could provide evidence, such as this systematic review, to adequately promote its benefits to the patient.

Based on these issues, the role of the CRNA would be to implement a system change. Certified Registered Nurse Anesthetists or a chief CRNA could meet with

management and administration of the hospital to discuss implementation of this practice. Outlining the benefits to patients and the relationship to outcomes would be helpful with achieving consensus to buy the proper equipment and ensure proper use in the preoperative area. As for teaching or training staff, the forced-air warming units are extremely user friendly. Preoperative nurses and anesthesiologists could be trained on setup and use of the forced-air warming unit for the patient in the preoperative area. Simply plugging the air hose into the gown and turning it on are the majority of the technical skills needed to operate the unit. However, teaching other CRNAs about utilizing the forced-air warming units during the intraoperative would also be important. For some shorter cases, CRNAs may not use the warmer or only turn it on once the patient becomes hypothermia. A teaching presentation could help convey the importance to use the equipment available to those involved to ensure patient safety and improve outcomes.

Further research about warming time during the preoperative period would benefit the use of this practice. The studies assessed all had similar, but not consistent times of warming. Some of the studies reported that patients reported feeling too hot during prewarming and asked for the device to be turned off. Identifying the minimal effective time of preoperative forced-air warming would give advanced practice nurses a better guideline to treat their patients. There are minimal ethical considerations for preoperative forced-air warming. If patients feel warm, simply shutting the forced-air warmer off would be adequate to promote the patient's thermal comfort. The older adult population would certainly benefit from this as they have a reduced shivering threshold (Jo et al. 2015) and experience hypothermia at a greater rate than younger adults.

Another possible idea for further research would be to assess forced-air warming units against other types of warming such as circulating water mattresses, warm blankets, carbon-fiber blankets. Ambient temperatures could also affect patients' temperatures and warming mechanism, which could be another area of IPH worth looking into for more research.

Implementation of preoperative forced-air warming would benefit patient's comfort and outcomes by mitigating the incidence and adverse consequences of IPH. The workloads of advanced practice nurses and nurses in the perioperative environment would not be significantly impacted. The advanced practice nurse has a significant role in providing the most effective care to patients, with minimal adverse effects.

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Appendix A

Data Extraction Tables

Table A1.

Andrzejowski, J., Hoyle, J., Eapen, G., & Turnbull, D. (2008). Effect of prewarming on post-induction core temperature and the incidence of inadvertent perioperative hypothermia in patients undergoing general anaesthesia. *British journal of anaesthesia*, *101*(5), 627-631.

Setting/Sample	Method/Design	Time of preoperative warming and device, Intraoperative temperature device and site	Temperature setting of FAW	Patient intraoperative temperature	Patient postoperative temperature	Limitations
ASA physical status I and II patients, undergoing general anesthesia for elective spinal surgery. In order to detect a difference of 0.28° C in mean core temperature between the groups,	The patients were randomized using a computer-generated randomization to two groups: a prewarmed group and a non-prewarmed group. Propofol target-controlled infusion was used in	About 60 minutes using the Bair Paw`s® gown Esophageal temperature probe inserted to about 15 cm deep. Intraoperative warming continued if	Preoperative @ 38° C, this temperature setting was maintained into the intraoperative period. No intraoperative fluid warming	Recorded immediately after induction at 20 minute intervals for the duration of the surgery. Significantly smaller decrease in core temperature in prewarmed	The study did not report postoperative temperatures, but strictly intraoperative temperature. It did record how many patients were still under	Not even number of participants and one group (prewarmed) did not have the adequate sample size for the power analysis and significance

with a power of 0.8 and a significance level of $p < 0.05$, the sample size for each group was calculated to be 35. 8 surgical cancellations N = 68 participants Prewarmed n = 31 Non-prewarmed n = 37	the majority of patients supplemented with either remifentanil or alfentanil infusion. Two patients in each group received sevoflurane for maintenance.	prewarmed, initiated if non-prewarmed.	or other warming methods used	group at 40,60, 80 minutes. Change in core temperature Prewarmed = 0.4, 0.5, 0.5 Non-prewarmed = 0.8, 0.8, 0.7 Mean difference in temperature 20 mins = 0.2 40 mins = 0.3 60 mins = 0.3 80 mins = 0.3 100 mins = 0.3 120 mins = 0.3 140 mins = 0.1 160 mins = 0.0 3 patients (8%) were hypothermic in non-prewarmed group.	anesthesia at the time intervals though. However, patients temperatures were recorded throughout and results showed patients remained normothermic throughout surgery in the prewarmed group (68%) compared with the control group (43%). Both ($p < 0.05$)	level. Only ASA I, II patients No standard time frame, some cases were much longer than others. Blinding difficult to achieve as the nature of prewarming during preoperative period.

Table A2.

Horn, E. P., Bein, B., Böhm, R., Steinfath, M., Sahili, N., & Höcker, J. (2012). The effect of short time periods of pre- operative warming in the prevention of peri- operative hypothermia. *Anaesthesia, 67*(6), 612-617.

Setting/Sample	Method/ Design	Time of preoperative warming and device, Intraoperative temperature device and site	Temperature setting of FAW	Patient intraoperative temperature	Patient postoperative temperature	Limitations
ASA physical status I and II patients, undergoing elective laparoscopic cholecystectomy, inguinal hernia repair, breast surgery, minor orthopedic surgery, and ENT surgery. n = 200 Patients divided into four groups, estimated to provide 80% power for detecting	Patients were randomly assigned to one of the four treatment groups: passive insulation (no active warming) or active preoperative forced-air warming for 10, 20 or 30 mins. Randomization was performed by rolling a modified dice with four faces each representing one of the four treatment groups. Active warming during surgery only required if patient became	0, 10, 20, or 30 mins Core temperature measured continuously using a tympanic temperature sensor.	A Level 1 Equator® warmer set to high (44° C) and started depending on which group each patient was in. A countdown timer was used to ensure correct duration. If patients were too warm, warmer turned down to 40° C. Ambient temps maintained at 23° C throughout perioperative	Patient characteristics, surgical duration, room temperatures all comparable between groups Eight of the 200 patients (4%) were already hypothermic on arrival at the preop, one in the group without prewarming. and 3, 1 and 3 in the respective 10-, 20- and 30-min pre-warming groups. At the start of surgery, non-prewarmed patient still hypothermic the	PACU temps found NPW = 69% 10 min = 13% 20 min = 7% 30 min = 6% to be hypothermic. No significance (p = 0.54) between prewarmed groups	No patients under 18, no patients planned for combined general/ regional anesthesia. Patients were hypothermic prior to start of study. Distribution of surgery types was not equal throughout all

a statistically significant difference at an alpha level of 0.05.	hypothermic (36° C). After the pre-warming procedure, patients were transferred to OR. General anesthesia was induced with propofol/ sufentanil and maintained with sevoflurane by an anesthetist blinded to the pre-warming group of the patient. An endotracheal tube or LMA was inserted depending on the standard protocol for the surgical procedure. Atracurium was used for neuromuscular blockade.		period.	other seven patients became normothermic during the pre-warming procedure. Non-prewarmed patients temperatures were decreased dramatically versus the prewarmed groups from 15 minutes after start of surgery into the PACU period. Core temps of prewarmed groups were similar. Patients requiring active warming during surgery/ in PACU NPW = 67%/65% 10 mins = 31%/13% 20 mins = 2%/2% 30 mins = 6%/8% .		groups. All fluids heated to 39° C per hospital policy, but no active fluid warming intraop

Table A3.

Nicholson, M. (2013). A comparison of warming interventions on the temperatures of inpatients undergoing colorectal surgery. *AORN journal*, *97*(3), 310-322.

Setting/Sample	Method/Design	Time of preoperative warming and device, Intraoperative temperature device and site	Temperature setting of FAW	Patient intraoperative temperature	Patient postoperative temperature	Limitations
Tertiary hospital w/ 731 beds (3,500 general surgical procedures/yr) Adults scheduled for elective colon procedures, and had a core temperature reading < 37° C. Desired power of 0.8 and calculated out to estimate sample size of 44. Planned for 30% over enrollment (planning for attrition) n = 32 participants (48.5%) were randomly assigned to the control group: an unwarmed blanket. n = 34 participants (51.5%)	Patient informed consent obtained and placed patient names into permuted blocks and computer-generated randomization list for either control or intervention group. Knowledge of the next assignment was not available to the person obtaining consent until after enrollment occurred.	Oral temperature for all patients initially. All patients prewarmed received at least 30 mins of warming using forced-air warming gown. Intraoperative temperatures were obtained from either a urinary catheter or a nasal, esophageal, or oral thermistor.	Specific temperature of forced-air warming not provided.	Ambient temperatures were comparable. First temperature recording following induction was used Mean intraop temperatures: Control = 35.88° C Experimental = 36.12° C Found to not be statistically significant (p = 0.05)	PACU temperature recorded within 15 minutes of arrival Mean temperatures: Control = 36.63° C Experimental = 36.75° C (p = 0.05) Found to not be statistically significant (p = 0.05) All 34 patients (100%) in the experimental	Lack of dedicated personnel. Difficulty obtaining immediate postop temperatures. Facility policy to warm patient intraop prior to induction. Variability of temperature devices utilized. Patients received warmed irrigation fluids in open cases

were randomly assigned to the experimental group: temperature controlled by using a forced-air warming gown.		Mean admission temperatures between groups found to be comparable. The total time of preoperative warming was a mean of 75.35 minutes.			group had postoperative oral temperatures higher than 36_ C (96.8_ F) within 15 minutes of arrival in the PACU compared with 32 patients (91%) in the control group.	and warmed IV fluids.

Table A4.

Horn, E. P., Bein, B., Broch, O., Iden, T., Böhm, R., Latz, S. K., & Höcker, J. (2016). Warming before and after epidural block before general anaesthesia for major abdominal surgery prevents perioperative hypothermia: A randomised controlled trial. *European Journal of Anaesthesiology (EJA)*, *33*(5), 334-340.

Setting/Sample	Method/Design	Time of preoperative warming and device, Intraoperative temperature device and site	Temperature setting of FAW	Patient intraoperative temperature	Patient postoperative temperature	Limitations
After obtaining written informed consent, inclusion of 99 adult patients scheduled for elective major abdominal surgery under combined general anesthesia and epidural anesthesia with an expected duration of at least 120 min. Exclusion if under 18, classified as ASA 4 or greater, or refused epidural.	Patients were randomly assigned to one of three treatment groups: passive insulation but no active warming of the skin before the start of the surgery (‘no warming’) n = 32, active preoperative forced-air warming for 15 min after epidural catheter insertion and application of the	Level 1 Snuggle Warm Upper Body Blanket used for forced-air warming using Level 1 Equator warmer. Times of prewarming: No warming, 15 mins after epidural placement, 15 mins before and after epidural	Set to high (44° C) If patients were too warm, warmer turned down to 40° C. None for this particular study asked for warming to be turned down.	Temperature recorded every hour while intraop. 15 mins after first warming /15 mins after second warming. No warming = 32.6/31.8 Warming after epidural = 32.3/34.0	Temperature recorded upon arrival to ICU. In patients without warming, mean core temperature was 0.9° C lower compared with baseline values on arrival at ICU. 72% of these patients were hypothermic. ‘Warming after epidural’ group, core temperature on arrival at ICU was not significantly different from the baseline and	All fluids warmed to 41° C. Laparoscopic procedures versus open. Unable to blind patients.

A sample size of 99 patients, divided into three groups, was estimated to provide 80% power for detecting a statistically significant difference at a level of 0.05.	test dose but before injection of 6 to 8ml of ropivacaine 0.2% (‘warming after epidural catheter placement’) n = 33, or active preoperative forced-air warming for 15 min before insertion of the epidural catheter and for 15 min after insertion of the epidural catheter and administration of the test dose but before injection of 6 to 8ml of ropivacaine 0.2% (‘warming before and after epidural catheter placement’) n = 34. General anesthesia was induced using propofol 1.5 to 2.5mg/kg and sufentanil 0.2mg/kg, and was maintained with	placement. Core temperature measured continuously using a tympanic temperature sensor. Ambient temps maintained at 23° C throughout perioperative period. Preop temperatures did not differ between 3 groups.		Warming before and after epidural = 34.6/35.3 ($p < 0.05$)	1.0° C higher than in the patients without warming. 2 patients hypothermic at end of surgery. ‘Warming before and after epidural’ group, core temperature on arrival at ICU had increased by 0.7° C compared with the baseline value and was significantly higher than in the unwarmed patients (+1.5° C) ($p < 0.05$). 34% of patients in ‘no warming’ remained intubated into ICU and had a mean time of 36 mins of mechanical ventilation compared to 0% in ‘warming after epidural’ and ‘warming before and after epidural’ groups.	

	sevoflurane (0.7 to1.0 minimum alveolar concentration) by an anesthesiologist blinded to the warming randomization. Atracurium (0.5mg/kg) was used for muscle relaxation and an endotracheal tube was inserted. Randomization achieved by uninvolved preop RN rolling dice.					

Table A5.

Jo, Y. Y., Chang, Y. J., Kim, Y. B., Lee, S., & Kwak, H. J. (2015). Effect of preoperative forced-air warming on hypothermia in elderly patients undergoing transurethral resection of the prostate. *73*(6), 72-4.

Setting/Sample	Method/ Design	Time of preoperative warming and device, Intraoperative temperature device and site	Temperature setting of FAW	Patient intraoperative temperature	Patient postoperative temperature	Limitations
Fifty male patients > 65 yrs old, ASA I – II, elective TURP. Excluded if pre-anesthetic temp > 37.5° C or < 36° C, uncontrolled HTN or DM, or a condition requiring fluid restriction. Patients arrived to preoperative are and randomized to receive forced-air pre-warming (n=25) or not (control group n=24). Patients were not pre-medicated.	Temperature measure at arrival, 10 mins, 20 mins in preop. Brought to OR for spinal using 0.5% hyperbaric bupivacaine by blinded anesthesia provider. All patients were placed on warming mattress containing circulating water at 36° C.	20 mins of warming using WarmTouch forced-air warmer Temperature was measured perioperatively using infrared tympanic thermometer,	38° C for those who were a part of pre-warming group. Preop maintained at 21-23° C, while OR maintained at 24-25° C Warming mattress containing circulating water at 36ºC was applied on the operating table (No intraop forced-air warming). One layer of surgical drapes	Incidence of intraoperative hypothermia was higher in control groups (15/24 or 62.5%) vs. pre-warmed group (10/25 or 40%), but found to not be statistically significant. $p = 0.259$ Both groups experienced a significant decrease in core temperature during intraoperative period ($p < 0.001$). However, severities of hypothermia were significantly different	10 (40%) prewarmed patients were hypothermic compared to 13 (54%) control patients. Not significantly significant $p > 0.05$	Forced-air warming using for pre-warming, not maintained for all patients throughout perioperative period. Elderly patients have thermoregulatory changes and 20 mins may not have been enough. Restriction to elderly males, can not generalize results to elderly

To detect a mean intergroup difference in the incidence of hypothermia, 23 subjects were required with type I error (an α error of 0.05) and type II error (a β error of 0.2), and to account for possible losses, we included 25 patients per group. No significant differences were observed between the two groups in terms of sensory block level, volume of irrigation fluid, or total amount of intravenous fluid infused during TURP.			over all patients.	(p = 0.019). No patient in pre-warmed group showed moderate or profound hypothermia, while the control groups showed 21% and 13% respectively.		women.

Table A6.

Fettes, S., Mulvaine, M., & Van Doren, E. (2013). Effect of preoperative forced-air warming on postoperative temperature and postanesthesia care unit length of stay. *AORN journal*, *97*(3), 323-328

Setting/Sample	Method/ Design	Time of preoperative warming and device, Intraoperative temperature device and site	Temperature setting of FAW	Patient intraoperative temperature	Patient postoperative temperature	Limitations
18-85, ASA I to III at community hospital Exploratory laparotomy, colorectal surgery, total joints, spinal and chest procedures, total abdominal hysterectomy, robotic assisted nephrectomy, prostatectomy, and cystectomy. Excluded those with thyroid disease, autonomic dysfunction, Cushing's, or PVD (altered temperature),	Prospective, pretest/posttest randomized design. Once consented, randomization using patient account numbers was used. 128 total participants after dropouts, case cancellations.	Approximately one hour before surgery, patient placed under forced-air warming blanket and set to medium. Temporal artery-scanning thermometer utilized (supposedly permanent calibration design). Device used for warming not reported by study	Forced-air warming blankets set at "medium" 100° F (37.8° C) setting for warming	Nurse recorded preoperative, intraoperative and postoperative temperatures Forced-air warming was utilized for both groups intraop Exiting preop temperature: Control= 36.8° C Intervention = 37° C p = .314	Admission to PACU temperatures Control = 36.6° C Intervention = 36.7° C p = .314 Not statistically significant	Uneven distribution of intervention group to control group. Lack of patients with hypothermia in either group. Question if nurses in preop gave warm blankets to patients (unlikely related to time spent in this area).

admission temps > 37.5° C or < 36.5° C or known infection/fever. Convenience sample of 146 initial consent. Intervention group n = 54 Control group n = 74 (To detect a moderate effect size of 0.5 with 80% power, a sample size of 64 patients in each group was deemed necessary)						

Appendix B

Critical Appraisal Skills Programme (CASP) Tables

Table B1.

Andrzejowski, J., Hoyle, J., Eapen, G., & Turnbull, D. (2008). Effect of prewarming on post-induction core temperature and the incidence of inadvertent perioperative hypothermia in patients undergoing general anaesthesia.

Question	*Yes*	*Can't Tell*	*No*
Did the trial address a clearly focused issue? Yes, the purpose of the study was to evaluate the effect of prewarming on post-induction core temperature and the incidence of IPH. A sample of ASA I, II patients undergoing spinal surgery using general anesthesia was recruited. The intervention utilized was a forced-air warming device (Bair Paws®) in the preoperative period for ≈60 minutes.	☒		
Was the assignment of patients to treatments randomized? A computer-generated randomization process was used to divide the participants into two groups: a prewarmed group and a non-prewarmed group.	☒		
Were all of the patients who entered the trial properly accounted for at its conclusion? 76 patients were recruited, but 8 were excluded due to cancellations including 31 patients in the prewarmed group versus 37 in the non-prewarmed group. Patients remained in the assigned group and received the assigned intervention.	☒		
Were patients, health workers and study personnel blinded? Blinding was difficult to achieve in this study. Patients were awake in the preoperative setting and aware of the active warming. Some made comments about their thermal comfort preoperatively. However, this was not an outcome.			☒
Were the groups similar at the start of the trial? Patient characteristics, ward, operating room environmental temperatures, core temperatures at induction, duration of surgery, and infused fluid volumes were comparable between groups. No significant differences between cervical or lumbar spine surgeries or in ratio of male to female patients were noted.	☒		

Aside from the experimental intervention, were the groups treated equally? Both groups received the same intraoperative forced-air warming temperature (38° C). Cervical surgery received a full body blanket while lumbar surgery used a surgical access warming blanket.			
How large was the treatment effect? A significantly smaller decrease in core temperature was detected in the prewarmed group at 40, 60, and 80 minutes. The authors also surmised that the core temperature of the prewarmed group (-0.5° C lower than preoperative temperature) was greater than the control group (-0.6° C lower than preoperative temperature). A larger proportion of patient remained normothermic throughout surgery in the prewarmed group (68%, n = 21) compared with the control group (43%, n = 16).			
How precise was the estimate of the treatment effect? In order to detect a difference of 0.2° C in mean core temperature, the authors calculated the sample size of each group to be 35. This would provide them with a power of 0.8 and a significance level of 0.05.			
Can the results be applied in your context? (Or to the local population?) These results directly apply to the context of this systematic review. Prewarming was used to assess its efficacy of combating IPH in the patient undergoing general anesthesia. Temperatures were assessed and recorded throughout the perioperative period. The patient population fits the systematic review's inclusion criteria.			
Were all clinically important outcomes considered? All of the outcomes to be assessed in this systematic review were present in this study. However, temperature recordings every 20 minutes were not differentiated to intraoperative versus postoperative related to difference in surgical time.			
Are the benefits worth the harms and costs? A total of 5 patients developed nausea, 4 of which vomited. 5 patients developed shivering. There were no other complications noted. These complications are always potentially present with general anesthesia and may not be related to the intervention. The benefits outweigh the risks..			

Table B2.

Horn, E. P., Bein, B., Böhm, R., Steinfath, M., Sahili, N., & Höcker, J. (2012). The effect of short time periods of pre- operative warming in the prevention of peri- operative hypothermia. *Anaesthesia*, *67*(6), 612-617.

Question	***Yes***	***Can't Tell***	***No***
Did the trial address a clearly focused issue? The purpose of the study was to evaluate the performance of different durations of active prewarming to prevent IPH and postoperative shivering. A sample of ASA I, II adults undergoing general anesthesia for elective surgery were studied. The procedures included laparoscopic cholecystectomy, inguinal hernia repair, breast surgery, minor orthopedic surgery, and ENT surgery. Patients were divided into four groups: no prewarming active prewarming for 10, 20, and 30 minutes at 44° C by the Level 1 Equator® warming system.	☒		
Was the assignment of patients to treatments randomized? Rolling a modified dice with four faces randomized the patients, each representing one of four treatment groups.	☒		
Were patients, health workers and study personnel blinded? The anesthetist was blinded to the prewarming randomization when the patient was transported to the operating room. The patients were not able to be blinded and were aware of the warming period, but it is unlikely this would have effected the results.		☒	
Were the groups similar at the start of the trial? Patients were undergoing similar surgery and anesthetic delivery. Patients' characteristics, duration of surgery and ambient room temperatures were not different between groups. Age, sex, weight, and duration of surgery were also comparable throughout the treatment groups.	☒		
Aside from the experimental intervention, were the groups treated equally? All patients' core temperature was measured at the tympanic membrane continuously. Patients from all groups were covered with cotton blankets intra- and postoperatively. If temperature decreased below 36° C, active warming was initiated via an upper warmer, regardless of treatment group. All patients received fluids warmed to 39° C. Blood loss and volume of infusions was comparable through all groups.	☒		

Were all of the patients who entered the trial properly accounted for at its conclusion? All 200 patients were investigated up to the end of the protocol and interventions. The four treatment groups were not exactly equal, but all participants completed.	☐		
How large was the treatment effect? **Fifteen** minutes after the start of surgery, the non-prewarmed group temperatures decreased significantly compared to the prewarmed patients. At the start of the PACU, 38 out of 55 patients (69%) in the non-prewarmed group were hypothermic. The prewarmed groups of 10, 20, and 30 minutes were found to be hypothermic at 7 of 52 (13%), 3 of 43 (7%), and 3 of 50 (6%), respectively ($P < 0.05$). There was no significance between the three prewarmed groups ($P = 0.54$)	☐		
How precise was the estimate of the treatment effect? The study calculated that a sample size for an expected treatment effect of 0.5° C on postoperative temperature, a sample size of 200 for all groups would provide a power of 0.8 and significance level of 0.05.	☐		
Can the results be applied in your context? (Or to the local population?) The results of this study are appropriate for this systematic review. The general surgery patients undergoing general anesthesia had intraoperative and postoperative temperatures recorded, while assessing efficacy of prewarming. The patient population and study fits the systematic review's inclusion criteria.	☐		
Were all clinically important outcomes considered? Intraoperative and postoperative temperatures were recorded and assessed. There were 3 intervention groups and an individual control group. Postoperative shivering was also documented, but is not pertinent to this systematic review	☐		
Are the benefits worth the harms and costs? No adverse outcomes were reported in the study other than shivering, which was assessed in less than 9% of all patients in the study. The benefits outweighed the risks in this study.	☐		

Table B3.

Nicholson, M. (2013). A comparison of warming interventions on the temperatures of inpatients undergoing colorectal surgery. *AORN journal*, *97*(3), 310-322.

Question	***Yes***	***Can't Tell***	***No***
Did the trial address a clearly focused issue? The focus of the study was to assess patients' perioperative temperatures using two different warming interventions. One group was prewarmed using forced-air warming for at least 30 minutes and the other group was given one cotton blanket. The patient population consisted of adult patient scheduled for surgical colon procedures. The study was conducted in a tertiary hospital.	☒		
Was the assignment of patients to treatments randomized? Using the method of permuted blocks and a computer-generated randomization list randomized patients.	☒		
Were all of the patients who entered the trial properly accounted for at its conclusion? One hundred thirty-three patients were approached, 84 of which agreed. Based on exclusion criteria, 66 patients met the criteria and all 66 patients were able to complete the study and protocol as designed.	☒		
Were patients, health workers and study personnel blinded? Knowledge of the assignment group of patients was not available to the person obtaining consent until after patients were enrolled. There was no information on whether temperature readers or staff was blinded for the study.		☒	
Were the groups similar at the start of the trial? The authors report that the "typical" patient for the study was 59 years old, no difference in likelihood of male or female, Caucasian, and underwent laparoscopic colon surgery. There was a total of 32 control group participants and a total of 34 treatment group participants.		☒	
Aside from the experimental intervention, were the groups treated equally? Preoperative and postoperative temperatures were measured with oral thermometers for all patients, while intraoperative temperatures were recorded with either a rectal, esophageal, or urinary catheter temperature probe. Environmental temperatures in the operating room were similar for both groups. A majority of			☒

participants in both groups were given warmed irrigation fluids, warmed humidified gases through the ventilator and warmed IV fluids, but a table shows that not all patients received these measures. Also, the mean preoperative warming occurred at a mean of 75.35 minutes with a standard deviation of 56.10 minutes. All patients in the prewarmed group did not receive the same warming time frame. All patients received intraoperative forced-air warming			
How large was the treatment effect? The authors observed 34 (100%) of the experimental group patients to be normothermic within 15 minutes of arrival to PACU as compared to 32 (91%) in the control group. No significant differences in the proportion of patients who experienced hypothermia in the perioperative period after receiving forced-air warming compared to a cotton blanket were detected ($p = 0.05$)	☐		
How precise was the estimate of the treatment effect? A desired power of 0.8 and significance level of 0.05 for this study required a sample size of 44 based on the author's calculations.	☐		
Can the results be applied in your context? (Or to the local population?) The results from this study can be applied to this systematic review. The sample of adults undergoing general anesthesia for colon surgery fits inclusion criteria. Prewarming with forced-air units was used to assess its efficacy at preventing IPH, although some interventions were not equal in all patients and could have potentially affected results.		☐	
Were all clinically important outcomes considered? Perioperative temperatures were recorded for all patients in each of the two treatment groups and compared. The differences were not clinically significant, but there were some measurable differences in postoperative temperatures between the groups. The author also listed several limitations to the study including dedicated researchers, differences in temperature measuring device, and intraoperative warming prior to induction of anesthesia.		☐	
Are the benefits worth the harms and costs? The study did not report any adverse events or outcomes from the participants from hypothermia or hypothermia related complications. The benefits were worth the harms and costs for this particular study.	☐		

Table B4.

Horn, E. P., Bein, B., Broch, O., Iden, T., Böhm, R., Latz, S. K., & Höcker, J. (2016). Warming before and after epidural block before general anaesthesia for major abdominal surgery prevents perioperative hypothermia: A randomised controlled trial. *European Journal of Anaesthesiology (EJA), 33*(5), 334-340.

Question	***Yes***	***Can't Tell***	***No***
Did the trial address a clearly focused issue? The purpose of the study was clearly defined as evaluation of the effects of active skin-surface warming before and/or after initiation of epidural analgesia during general anesthesia as a procedure to prevent IPH. Ninety-nine adult patients were divided into three groups: passive insulation, 15 minutes of active air-forced warming after epidural analgesia and before induction of general anesthesia, or 15 minutes of active air-forced warming before and after epidural analgesia. The primary outcome measured was incidence of hypothermia on arrival to the ICU.	☒		
Was the assignment of patients to treatments randomized? Yes, the assignment of patients was randomized to one of three groups. This was conducted by an uninvolved nurse on arrival at the preoperative care unit by rolling a dice. A roll of 1 or 4 resulted in enrollment to the "no warming" group. A roll of 2 or 5 resulted in enrollment to the "warming after epidural" group. A roll of 3 or 6 resulted in enrollment to the "warming before and after epidural" group.	☒		
Were all of the patients who entered the trial properly accounted for at its conclusion? All 99 patients who started the trial were able to complete the procedure in their intended groups: n = 32 in "no warming"; n = 33 in "warming after epidural"; and n = 34 in "warming before and after epidural".	☒		
Were patients, health workers and study personnel blinded? Anesthesiologists that performed the intraoperative aspects of the case were blinded to the patient warming randomization. The patient could not be blinded as they were awake during the preoperative period and epidural placement.	☒		
Were the groups similar at the start of the trial? No deviation from a normal distribution for tympanic temperatures, age, height, weight, or BMI was reported.	☒		

Each group contained a similar number of patients, but were not exactly even.			
Aside from the experimental intervention, were the groups treated equally? Patients were premedicated with similar doses of midazolam. An IV was placed, fluids started at the same rate and warmed to the same temperature by a fluid warmer. Epidurals were all placed using the same technique between either T8/9 or T9/10 thoracic interspaces. Doses of ropivacaine 0.75% were given based on patient height. All groups received upper body forced-air warming using a Level 1 Equator warmer (44° C). Core temperatures were continuously measured at tympanic membrane using temperature sensor. Time increments of temperature recordings were constant throughout and all patients were transferred to the ICU. Patients were only extubated in ICU if their temperature was greater than 35.5° C and vital signs were stable.	□		
How large was the treatment effect? 72% of patients in the "no warming" group were hypothermic on arrival to the ICU. In the "warming after epidural group", only 6% of patients were hypothermic on arrival to ICU, while the "warming before and after epidural" had 0% of the group be hypothermic in ICU. Results showed that active forced-air warming 15 minutes before and after epidural placement and prior to general anesthesia was sufficient to prevent hypothermia in all their patients undergoing major abdominal surgery.	□		
How precise was the estimate of the treatment effect? 0.5° C is the smallest difference that has been shown to be associated with hypothermia-induced complications. For that reason, the authors calculated a sample size of 99 patients divided into 3 groups, would provide a 0.8 power and a significance level of 0.05.	□		
Can the results be applied in your context? (Or to the local population?) These results can certainly be applied to this systematic review. The sample of adult patients undergoing neuraxial and general anesthesia for abdominal surgery fits the inclusion criteria. Different treatment groups for preoperative forced-air warming to combat IPH was investigated in the study and follows the aim of this review.	□		
Were all clinically important outcomes considered? Yes, all the important outcomes were considered. Perioperative temperatures were recorded for each patient. The three treatment groups received different warming techniques, but all other variables were consistent. The main outcome was core temperature on arrival to the postoperative ICU.	□		
Are the benefits worth the harms and costs? The benefits of the study were worth the harm and cost for this study. Some patients remained intubated for a short time in the "no warming" group until their temperature met the hospital policy for extubation following major abdominal surgery.	□		

Table B5.

Jo, Y. Y., Chang, Y. J., Kim, Y. B., Lee, S., & Kwak, H. J. (2015). Effect of preoperative forced-air warming on hypothermia in elderly patients undergoing transurethral resection of the prostate. *73*(6), 72-4.

Question	***Yes***	***Can't Tell***	***No***
Did the trial address a clearly focused issue? The authors stated an aim of investigating the effects of preoperative forced-air warming on perioperative hypothermia and shivering in elderly patients undergoing transurethral resection of the prostate (TURP) under spinal anesthesia only. Elderly (> 65 years old) males were assigned to one of two groups: "pre-warmed" group received 20 minutes of preoperative forced-air warming or "control" that received no preoperative warming. Outcomes were intraoperative and postoperative temperature reading.	☒		
Was the assignment of patients to treatments randomized? Patients were randomized into 1 of 2 groups, but they did not provide any information on how the randomization process was completed.		☒	
Were all of the patients who entered the trial properly accounted for at its conclusion? A total of 50 patients were recruited for this trial. All 25 patients in the control group were able to complete the trial, but 1 patient in the "pre-warmed" group did not complete the trial because the anesthetic technique changed to a general anesthesia case.			☒
Were patients, health workers and study personnel blinded? Spinal anesthesia was performed once patients were in the operating room. The anesthesia provider was blinded to which warming technique the patient received in the preoperative setting. The patient could not be blinded because they are alert and awake during the preoperative period.	☒		
Were the groups similar at the start of the trial? Males 65 years or older undergoing elective TURP and physical status I or II was included in the study. No significant differences were observed between the two treatment groups in terms of sensory block level, volume of irrigation fluid, or total amount of IV fluids.	☒		

Aside from the experimental intervention, were the groups treated equally? Patients did not receive any premedication. All patient temperatures were recorded using infrared tympanic membrane thermometers (ThermoScan IRT 1020). All those in the "pre-warmed" group received forced-air warming at 38° C for 20 minutes. Patients received 8-10 ml/kg/h of plasma solution hydration prior to surgery and ambient temperatures were consistently 21-23° C. OR temperatures were maintained at 24-25° C. Patient warming introperatively was maintained using circulating water mattress at 36° C. All patients were covered with one layer of surgical drapes over chest, thighs, and calves. If patient became hypothermic (36° C) or asked for warming, forced-air warming was used regardless of group.			
How large was the treatment effect? IPH in the pre-warmed group versus the control group was not statistically significant (40% vs. 62.5%;p = 0.259). However, the severities of hypothermia were found to be significantly different (p = 0.019). No patient in the "pre-warmed" group experienced moderate or profound hypothermia. In the control group, 21% were moderately hypothermic and 13% profoundly hypothermic. No significant difference in pre and postoperative temperatures was detected between groups, but during the intraoperative period, a significant decrease in core temperature (p < 0.001) was observed in both groups.			
How precise was the estimate of the treatment effect? The authors calculated a sample size of 23 patients per group to provide a power of 0.8 and a significance level of 0.05. The "pre-warmed" group had 25 patients and the control group had 24 participants.			
Can the results be applied in your context? (Or to the local population?) Yes, the results of this study can be applied to the context of this systematic review. Prewarming of adult patients to undergo surgery using spinal anesthesia fits the inclusion criteria. Prewarming was conducted using forced-air warming and intraoperative warming was consistent for two groups.			
Were all clinically important outcomes considered? Temperature recording during the perioperative period were used to assess the efficacy of preoperative forced-air warming versus no warming in the adult patient.			
Are the benefits worth the harms and costs? The authors did not report any adverse outcomes in either group from hypothermia or hypothermia related complications. The data collected can benefit the medical community and the benefits outweigh the harms and costs.			

Table B6.

Fettes, S., Mulvaine, M., & Van Doren, E. (2013). Effect of preoperative forced-air warming on postoperative temperature and postanesthesia care unit length of stay. *AORN journal*, *97*(3), 323-328.

Question	***Yes***	***Can't Tell***	***No***
Did the trial address a clearly focused issue? Yes, the focus of the study was to compare the temperature of patients undergoing surgery who did not receive forced-air warming before induction of anesthesia with patients who did receive forced-air warming before anesthesia. Adult patients, with a physical status classification of I, II, or III, undergoing general anesthesia for a variety of procedures were studied. The procedures included exploratory laparotomy, colorectal surgery, total joint replacement (hip and knee), spinal and chest procedures, total abdominal hysterectomy, and robotic-assisted urological procedures.	☒		
Was the assignment of patients to treatments randomized? Nurses randomly assigned patients to the intervention or control group by using the last two digits of the patient's account numbers and random integers. If the two-number combination was on the sheet of 65 randomized number sets, then the patient was placed in the intervention group; if the pair of number wasn't on the sheet, then the patient was assigned to the control group.	☒		
Were all of the patients who entered the trial properly accounted for at its conclusion? All participants who started the study were able to complete the course of the study in their appropriate groups. Five patients dropped out of the study prior its initiation, 3 surgeries were cancelled, and 10 patients who were supposed to be a part of the study were not recognized by the nurse and did not participate.	☒		
Were patients, health workers and study personnel blinded? A sealed envelope was filled with patient information to be opened day of surgery. Preoperative nurses opened the envelope and either turned on the forced-air warming blanket or did not place one on the patient depending on which group they were assigned to. The PACU nurses received patients from both groups with their intraoperative warming blanket and were blinded to which group they were a part of.	☒		

Were the groups similar at the start of the trial? No significant differences between the two groups based on gender, age, body mass index, physical status classification, or hospital admission temperature were detected.	☒		
Aside from the experimental intervention, were the groups treated equally? All patients' temperature was recorded using a temporal artery-scanning thermometer. All thermometers were accurate to 0.2 ° C. Forced-air warming blankets were set to 37.8° C/medium setting. All warmers were inspected and tested prior to use. All patients received intraoperative forced-air warming, warmed IV fluids, and warmed irrigation fluids.	☒		
How large was the treatment effect? No significant differences in core temperature on arrival to PACU (p = 0.508) were detected. Only 0.1° C separated the mean core temperatures between groups, with the intervention group being slightly higher. The preoperative time for warming was roughly an hour; the authors did not report a set time frame for preoperative warming.	☒		
How precise was the estimate of the treatment effect? To detect a significance level of 0.05 with a power of 0.8, the authors calculated a sample size of 64 patients in each group. A total of 54 participants in the intervention group and a total of 74 patients in the control group were studied. The authors also found that PACU stay was no statistically significant between groups (p = 0.545).		☒	
Can the results be applied in your context? (Or to the local population?) The results for the study can be applied to this systematic review. The sample and study fit the inclusion criteria. However, there were some limitations to the study that may have altered the studies validity and may have contributed to the differences in final results from other studies of the same type.		☒	
Were all clinically important outcomes considered? Temperatures on arrival to PACU were assessed in two groups of adult patients receiving either preoperative forced-air warming or not for general anesthesia.		☒	
Are the benefits worth the harms and costs? The study reported no perioperative hypothermia events were detrimental to the health of any patients. The only adverse outcome described was 2 patients in the intervention group were too warm and asked the warming blanket to be turned off. Benefits outweighed the risks.	☒		

Appendix C

Critical Appraisal for Summaries of Evidence (CASE) Worksheet for Individual Studies

Table C1.

Andrzejowski, J., Hoyle, J., Eapen, G., & Turnbull, D. (2008). Effect of prewarming on post induction core temperature and the incidence of inadvertent perioperative hypothermia in patients undergoing general anaesthesia. *British journal of anaesthesia*, *101*(5), 627-631.

Questions	**Evaluation**
Summary Topic	
Is the summary specific in scope and application?	Yes
Summary Methods	
Is the authorship of the summary transparent?	Yes
Are the reviewer(s)/editor(s) of the summary transparent?	Yes
Are the research methods transparent and comprehensive?	Yes
Is the evidence grading system transparent and translatable?	Yes
Summary Content	
Are the recommendations clear?	Yes
Are the recommendations appropriately cited?	Yes
Are the recommendations current?	Not completely
Is the summary unbiased?	Yes
Summary Application	
Can this summary be applied to your patient(s)?	Yes

Table C2

Horn, E. P., Bein, B., Böhm, R., Steinfath, M., Sahili, N., & Höcker, J. (2012). The effect of short time periods of pre- operative warming in the prevention of peri- operative hypothermia. *Anaesthesia*, *67*(6), 612-617.

Questions	**Evaluation**
Summary Topic	
Is the summary specific in scope and application?	Yes
Summary Methods	
Is the authorship of the summary transparent?	Yes
Are the reviewer(s)/editor(s) of the summary transparent?	Yes
Are the research methods transparent and comprehensive?	Yes
Is the evidence grading system transparent and translatable?	Yes
Summary Content	
Are the recommendations clear?	Yes
Are the recommendations appropriately cited?	Yes
Are the recommendations current?	Yes
Is the summary unbiased?	Yes
Summary Application	
Can this summary be applied to your patient(s)?	Yes

Table C3.

Nicholson, M. (2013). A comparison of warming interventions on the temperatures of inpatients undergoing colorectal surgery. *AORN journal*, *97*(3), 310-322.

Questions	**Evaluation**
Summary Topic	
Is the summary specific in scope and application?	Yes
Summary Methods	
Is the authorship of the summary transparent?	Not completely
Are the reviewer(s)/editor(s) of the summary transparent?	Yes
Are the research methods transparent and comprehensive?	Yes
Is the evidence grading system transparent and translatable?	Yes
Summary Content	
Are the recommendations clear?	No
Are the recommendations appropriately cited?	Yes
Are the recommendations current?	Yes
Is the summary unbiased?	Not completely
Summary Application	
Can this summary be applied to your patient(s)?	Not completely

Table C4.

Horn, E. P., Bein, B., Broch, O., Iden, T., Böhm, R., Latz, S. K., & Höcker, J. (2016). Warming before and after epidural block before general anaesthesia for major abdominal surgery prevents perioperative hypothermia: A randomised controlled trial. *European Journal of Anaesthesiology (EJA), 33*(5), 334-340.

Questions	**Evaluation**
Summary Topic	
Is the summary specific in scope and application?	Yes
Summary Methods	
Is the authorship of the summary transparent?	Yes
Are the reviewer(s)/editor(s) of the summary transparent?	Yes
Are the research methods transparent and comprehensive?	Yes
Is the evidence grading system transparent and translatable?	Yes
Summary Content	
Are the recommendations clear?	Yes
Are the recommendations appropriately cited?	Yes
Are the recommendations current?	Yes
Is the summary unbiased?	Yes
Summary Application	
Can this summary be applied to your patient(s)?	Yes

Table C5.

Jo, Y. Y., Chang, Y. J., Kim, Y. B., Lee, S., & Kwak, H. J. (2015). Effect of preoperative forced-air warming on hypothermia in elderly patients undergoing transurethral resection of the prostate. *73*(6), 72-4.

Questions	**Evaluation**
Summary Topic	
Is the summary specific in scope and application?	Yes
Summary Methods	
Is the authorship of the summary transparent?	Yes
Are the reviewer(s)/editor(s) of the summary transparent?	Yes
Are the research methods transparent and comprehensive?	Yes
Is the evidence grading system transparent and translatable?	Yes
Summary Content	
Are the recommendations clear?	Yes
Are the recommendations appropriately cited?	Yes
Are the recommendations current?	Not completely
Is the summary unbiased?	Yes
Summary Application	
Can this summary be applied to your patient(s)?	Yes

Table C6.

Fettes, S., Mulvaine, M., & Van Doren, E. (2013). Effect of preoperative forced-air warming on postoperative temperature and postanesthesia care unit length of stay. *AORN journal*, *97*(3), 323-328.

Questions	**Evaluation**
Summary Topic	
Is the summary specific in scope and application?	Yes
Summary Methods	
Is the authorship of the summary transparent?	No
Are the reviewer(s)/editor(s) of the summary transparent?	No
Are the research methods transparent and comprehensive?	Not completely
Is the evidence grading system transparent and translatable?	No
Summary Content	
Are the recommendations clear?	Not completely
Are the recommendations appropriately cited?	Yes
Are the recommendations current?	Yes
Is the summary unbiased?	No
Summary Application	
Can this summary be applied to your patient(s)?	Not completely

Appendix D

Critical Appraisal for Summaries of Evidence (CASE) Worksheet for Cross Study Analysis

Critical Appraisal for Summaries of Evidence (CASE) Worksheet **Numbers in evaluation correspond with those assigned to articles in data extrapolation chart**	
Questions	**Evaluation**
Summary Topic	
Is the summary specific in scope and application?	Yes - 1, 2, 3, 4, 5, 6 Not completely- No-
Summary Methods	
Is the authorship of the summary transparent?	Yes - 1, 2, 4, 5, Not completely- 3, No-6
Are the reviewer(s)/editor(s) of the summary transparent?	Yes- 1, 2, 3, 4, 5 Not completely- No - 6
Are the research methods transparent and comprehensive?	Yes- 1, 2, 3, 4, 5 Not completely - 6 No -
Is the evidence grading system transparent and translatable?	Yes- 1, 2, 3, 4, 5 Not completely- No - 6
Summary Content	
Are the recommendations clear?	Yes- 1, 2, 4, 5 Not completely - 6 No - 3
Are the recommendations appropriately cited?	Yes - 1, 2, 3, 4, 5, 6 Not completely- No-
Are the recommendations current?	Yes - 2, 3, 4, 6 Not completely-1, 5 No-
Is the summary unbiased?	Yes - 1, 2, 4, 5 Not completely-3 No - 6
Summary Application	
Can this summary be applied to your patient(s)?	Yes - 1, 2, 4, 5 Not completely – 3, 6 No-