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Preprocedure Warming to Prevent Intraoperative Hypothermia

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by

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Abstract

Maintaining homeostasis during surgery is vital to preserving health and preventing postoperative complications. Research supports the benefits of preprocedure warming in preventing or reducing intraoperative hypothermia. Better postoperative outcomes are linked to intraop normothermia such as a reduction in the occurrence of surgical site wound infection, reduced bleeding, and faster recovery from anesthetics. However there were barriers to prewarming at the researcher's institution such as cost, convenience, and compliance. The purpose of this research project was to study the impact of prewarming in the high risk population of surgical spine fusion patients. The researcher also hoped to examine and raise awareness of barriers to prewarming. Although research results did not correlate prewarming directly to higher admission to operating room temperatures, there was a significant impact noted on other variables in this study indicative of the positive relationship of prewarming to intraoperative normothermia.

Keywords: hypothermia, prewarming, normothermia, wound infections

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TABLE OF CONTENTS

List of Figures

List of Tables

CHAPTER I

Introduction

Unplanned hypothermia during a surgical procedure is a contributing factor in various postoperative complications. The consequences of prolonged hypothermia involve the respiratory, cardiovascular, and adrenergic systems. Even mild hypothermia inhibits the metabolism of anesthetics and neuromuscular blocking agents delaying wake up from anesthesia prolonging the need for airway support. Stimulation of the sympathetic nervous system in response to hypothermia as well as fluctuations in serum potassium levels increases the chance of ventricular dysrhythmias. Hypothermia also impairs platelet function and alters the coagulation cascade resulting in increased bleeding (Weirich, 2008). Tissue hypoxia from vasoconstriction can lead to delayed wound healing. Hypothermia impairs neutrophil function and decreases the efficacy of macrophages and lymphocytes, predisposing the patient to possible surgical site infection. (Odom-Forren, 2009).

Surgical site infections (SSIs) occur in 2-5% of all surgical procedures performed in America. Patients who develop an SSI are 2 to 11 times more likely to die compared to those who do not develop this type of infection (Fencl et al., 2015, p. 28). Anesthesia providers utilize various techniques to try and maintain normothermia in a cold operating room where ambient room temperatures may drop to 60 degrees Fahrenheit (F) based on surgeon preference. Despite the anesthesia provider’s best efforts, hypothermia may occur due to multiple factors, but the main triggers are the effect of anesthesia on metabolic heat production and impaired thermoregulation as well as exposure to the cold perioperative environment (Cobbe et al., 2012).

Preventing hypothermia has been shown to reduce the likelihood of surgical site infections (SSIs) by 64% and subsequent length of hospital stays by as much as 40% (Weirich, 2008, p. 339). SSIs involving spine fusion cases have received much attention over the past few years. As possible factors in the development of wound infections in this population were examined, reducing intraoperative hypothermia became an important focus. During that time, the preoperative team at the research study site was utilizing a patient controlled warming gown prior to surgery to prewarm the patient to prevent hypothermia intraop. The cost to the hospital for the disposable gown which was not billable to the patient incurred an annual expense of $60,000. With budget cuts and other factors impacting the cost of health care at the hospital the warming gowns were eliminated. An alternative warming blanket was made available. However, utilizing it created convenience barriers due to the difference in technology associated with a larger warming unit required for the blanket and the need for temperature monitoring after application. The disposable forced air warming blanket could be utilized in the operating room which was cost effective. However, the blanket was more difficult to apply in the preoperative setting because the patient was required to lie down, the style of the blanket takes longer to apply, and the patient cannot control the temperature of the attached warming unit. An additional barrier to consistent compliance with prewarming was the manufacturer's recommendation to monitor the patient's temperature every 15 to 20 minutes after application of the blanket because of the increased air flow and higher heat settings with the larger warming unit. Nurses also faced resistance from the patient to application of a warming blanket when they reported not feeling cold in preop. Barriers to implementation led to noncompliance with application of the warming blanket in the preoperative area despite education to staff regarding the benefits of prewarming the patient to prevent intraoperative hypothermia and its resulting complications. With the rise in surgical site infections in spine fusion patients, preoperative and anesthesia staff members were re-educated in the importance of prewarming and the intraoperative use of the forced air warming blanket. This study examined the impact of prewarming in the spine fusion population to determine its effectiveness in the prevention or reduction in time the patient was hypothermic at the researcher’s institution.

Significance

Approximately 160,000 – 300,000 SSIs occur in the United States annually (Anderson et al., 2014). SSIs have an estimated direct cost of $20,785 per patient and an average additional length of stay between 7 to 11 days. Methicillin Resistant Staph Aureus (MRSA) SSIs have an estimated cost of $42,300 and an average length of stay of 23 days (Zimlichman et al., 2013). Annual health care expenditures for SSI in the United States may be as high as 10 billion dollars according to epidemiologists (Anderson et al., 2014). The World Health Organization has established extensive protocols to ensure safe surgical practices, and one of their recommendations is to utilize preprocedure prewarming to prevent hypothermia (WHO, 2009, p. 50).

Unplanned perioperative hypothermia is thought to occur from multiple factors. Associated risk factors for hypothermia include normal or low body mass index, age, female gender, and the duration of anesthesia. Rapid heat loss in the operative environment occurs through four different avenues. The most significant heat loss occurs via the processes of radiation and conduction accounting for 85% of the body’s loss of warmth (Lynch, Dixon, & Leary, 2010, p. 554). The most consistent trigger for radiant heat loss happens through vasodilation immediately following induction of anesthesia which allows warm blood from the body's core to mix with cold blood in the peripheral compartments of the legs and arms. This is known as core to periphery redistribution hypothermia and can reduce core body temperature by 0.5 – 1.5⁰ Celsius (Fossum, Hays, & Henson, 2001, p. 2). Radiant heat loss also transpires when clothing is removed during draping and skin is exposed to cold air. Conductive heat loss ensues when the body comes in contact with cold surfaces or fluid (Burns, Piotrowski, Caraffa, & Wojnakowski, 2010, p. 286). Ambient room temperature below 68⁰ Fahrenheit in the operating room keeps surfaces cold. The remaining 15% of heat loss occurs through the processes of convection and evaporation. Convection takes place when the surgical wound is open resulting in heat loss as air currents or liquids transfer across the patient's skin or tissue. Prep solutions drying on the patient's skin result in heat loss through evaporation. Respiratory exhalation and sweating also contribute to evaporative heat loss (Lynch et al., 2010).

Hypothermia in the surgical arena has been linked to impairment of the coagulation cascade, blunted respiratory function, cardiac irritability, decreased metabolism of anesthetics, and impaired wound healing. Hypothermia alters the function of neutrophils and macrophages, the body's natural defense against invading bacteria. Even mild hypothermia interferes with immune functions by impairing chemotaxis and phagocytosis of granulocytes, and macrophage mobility. Hypothermia also decreases the availability of tissue oxygen resulting in the reduced microbial killing power of neutrophils (Kurz, Sessler, & Lenhardt, 1996, p. 1210). An increase in bleeding at the surgical site may lead to hematoma formation which increases the risk of SSI.

Hypothermia has also been associated with a decrease in the partial pressure of oxygen predisposing the wound to bacterial wound infection and delayed tissue healing (Weirich, 2008). Maintaining normothermia intraop helps prevent vasoconstriction and its resulting decrease in tissue oxygenation which deters surgical site infection (Fiedler, 2001).

Purpose

The purpose of this retrospective study was to determine if patients undergoing spine fusion surgery that received prewarming utilizing a forced air warming blanket maintained normothermia intraop or had a reduction in time spent hypothermic. Normothermia was defined as a core temperature reading between 36° C and 38° C at the end of anesthesia. Previously cited research supports a decrease in postoperative complications when a patient remains normothermic throughout the perioperative period.

Theoretical Framework

Betty Neuman's Systems Model was utilized as the theoretical framework for the research because of her open systems approach to patient care which includes the client's dynamic interaction with environmental stressors. In the Neuman model, the patient is at the core of survival factors or energy resources. Surrounding the core are concentric rings which represent lines of resistance to stressors. The flexible line of defense is the first protective mechanism – when flexible it can expand to incorporate new technologies for staying well. The outer circle is the normal line of defense in the model representing a stability state. Expansion of this line of defense further protects the core (Alligood & Tomey, 2010). Relating this model to the research project, the patient in the central core was undergoing surgery. The first line of defense was his willingness to wear the prewarming blanket in preop allowing the nurse to explain its function in preventing intraop hypothermia. The normal line of defense represented his continued compliance or participation with prewarming for at least 30 minutes, allowing temperature monitoring, and reporting the possible need for temperature adjustment to prevent overwarming. Stressors included surgery, the cold perioperative environment, heat loss from post anesthetic vasodilation, convection, evaporation, and or radiation with possible bacterial invasion, etc. Primary prevention was the action taken by the nurse with the patient when a possible stressor was identified. The reaction had not taken place in preop, but the risk of intraop hypothermia was known. The primary prevention was prewarming in the preprocedure area to decrease the possibility of reaction with perioperative environmental stressors, predominantly hypothermia. The Model is presented in Figure 1.

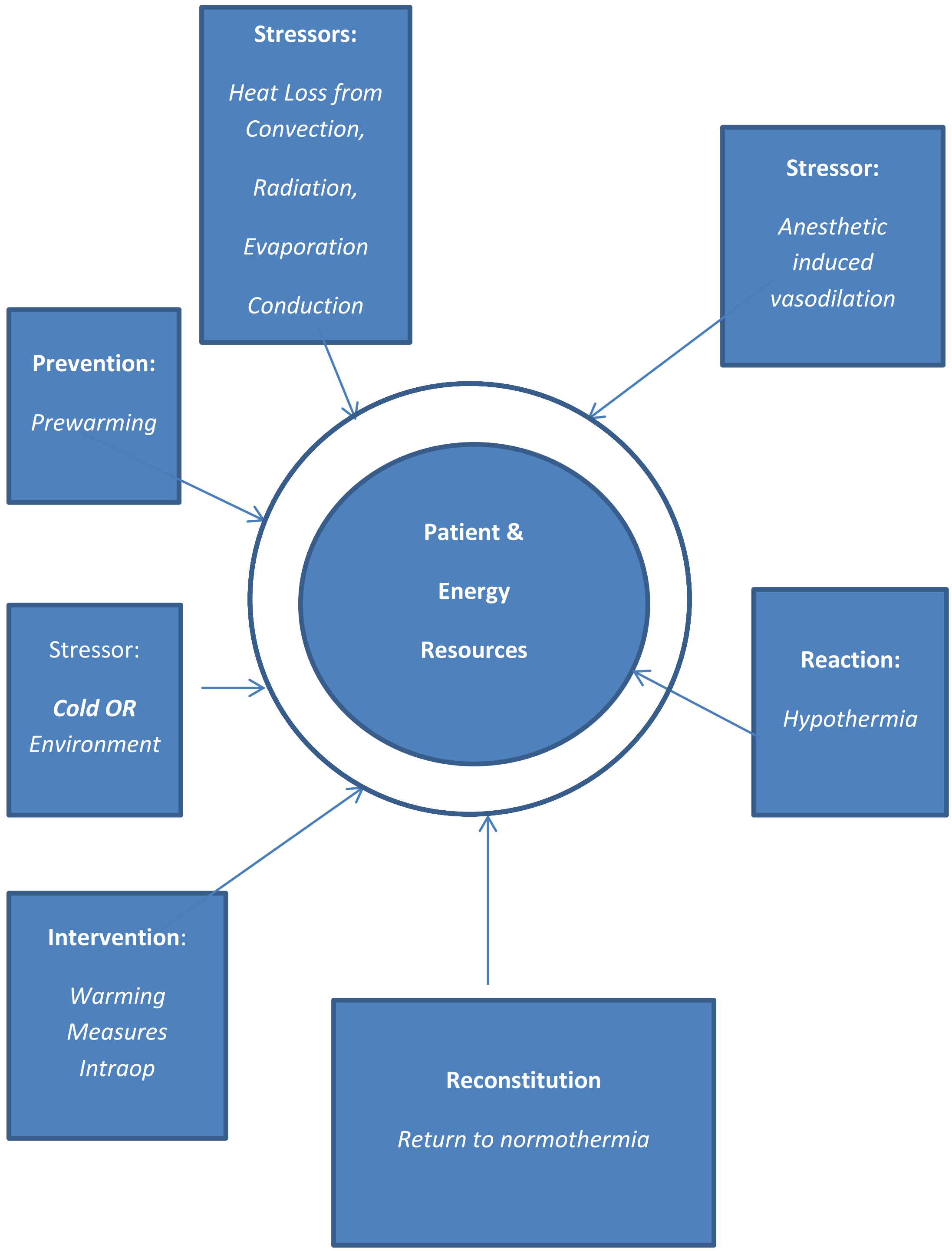

Figure 1. Neuman's Systems Model applied to intraoperative hypothermia has the patient in the central core or basic structure along with energy resources. The stressors surround the core along with the Intervention Prewarming to help return the patient to a normothermic state.

Thesis Question or Hypothesis

Continued barriers to prewarming related to application, convenience, and temperature monitoring prevented staff from consistently implementing pre-warming blankets prior to surgery despite education to staff. This study examined the effectiveness of prewarming in the prevention of intraop hypothermia. Patients who underwent spine fusion surgery are at higher risk for hypothermia due to the length of the case and the time needed to position the patient prior to implementation of warming measures intraop. Most of these procedures required positioning the patient in the prone position after intubation. This required on average about 30 thirty minutes during which time warming measures were delayed until the patient was positioned with protective measures in place.

The research question of interest was: In the spine fusion population, does the preoperative application of a forced air warming blanket for 30 minutes or more prevent intraoperative hypothermia (core temperature less than 36^{o} C) or reduce the time in minutes a patient is hypothermic intraop?

The research hypothesis was: The patient undergoing spine fusion surgery, when prewarmed for 30 minutes or more with the application of a forced air warming blanket, would not experience intraop hypothermia (core temperature less than 36 ^{o} C) or would have a reduction in hypothermia measured in minutes.

The study described intraoperative temperature ranges of spinal fusion patients receiving pre-procedure application of a forced air warming blanket versus those who did not, and the time in minutes patients who received pre-procedure application of a forced air warming blanket experienced intraoperative hypothermia versus those who did not.

Definition of Terms

Normothermia is defined as a core body temperature range between 36.5^{0} C and $37.^{0}$ C. Hypothermia is defined as a core body temperature below 36^{0} C. Mild hypothermia is described as a core temperature between 33^{0} C and 35^{0} C with the following possible complications:

- Decreased metabolism of the anesthetic or a prolonged wake up time
- Alteration in the clotting cascade resulting in increased bleeding
- Vasoconstriction and tissue hypoxia
- Impaired neutrophil and macrophage function (Fossum et al., 2001).

Prewarming is an intervention applied in the preoperative area utilizing a disposable warming blanket and a forced air warming device attached to the blanket by a connecting hose.

A surgical site infection is defined by the Centers for Disease Control (CDC) (1999) in three levels:

- A superficial incisional infection affecting the skin and subcutaneous tissue with localized symptoms of infection at the site
- A deep incisional infection affecting the fascia and muscle layers; symptoms may also include pus or an abscess along with separation of the wound edges
- An organ or space infection involving any part of the anatomy other than the incision; these are referred to as deep infections indicated by drainage of pus or abscess formation.

SSIs typically develop within 30 days of surgery; however an implant or use of hardware may cause an infection in the deeper tissues that is not apparent for several months (CDC, 1999, p. 251).

CHAPTER II

Literature Review

Surgical site infection (SSI) is a serious and common complication of surgery. Over the past three decades, intraop hypothermia has been implicated as a possible contributing factor in the development of wound infection. All anesthetics have been shown to alter thermoregulatory control via the core to peripheral redistribution of body heat that consistently results from the vasodilatation they cause (Sessler & Akca, 2002). Prewarming is an intervention used to counteract this well documented anesthetic consequence by warming the blood in the body's periphery thereby banking heat to counteract the redistribution that occurs from anesthesia. Reductions in core temperature predispose the body to SSI especially in the elderly and those with co-morbidities (Gould, 2012). The purpose of this thesis was to investigate if prewarming for 30 minutes or more maintained normothermia which is a core temperature of 36° - 38° C intraop in the spine fusion population.

The literature review was conducted using the following sources: Cumulative Index to Nursing and Allied Health (CINAHL), Medline, PubMed, Health Source, and Science Direct. Key words utilized in the literature search included hypothermia, perioperative, prewarming, and surgical site infection.

Hypothermia and Surgical Site Infections

In 1996, Kurz, Sessler, and Lenhardt investigated whether mild perioperative hypothermia is a risk factor for SSIs. Their study method involved 200 patients having colorectal surgery with half the population receiving intraop forced-air warming. Participants were evaluated daily while they were hospitalized and at two weeks postop.

Researchers were able to support their hypothesis that hypothermia triggers vasoconstriction which results in lower subcutaneous oxygen tension. With reduced tissue oxygen levels, neutrophils are less effective in their oxidative killing of invading bacteria which is the first line of defense. Conclusions of this study were that patients with a 2° C drop below normal temperature had three times the incidence of wound infection (Kurz et al., 1996, pp. 1,8).

Sessler and Akca measured subcutaneous oxygen tension and found that if it was greater than 90 mmHg, there were no wound infections. However, if the subcutaneous oxygen tension was found to be 40-50 mmHg, an infection rate of 43% occurred. A decrease in the oxygen tension was directly related to vasoconstriction, a consequence of hypothermia. This study underscored the impact of hypothermia on decreased perfusion, oxygen supply to the wound, as well as reduced production of superoxide radicals which aid in bacterial killing (Sessler & Akca, 2002).

Sessler continued his work with over 200 temperature-related studies, and in this article about his work, he discussed the thresholds for sweating, vasoconstriction, and shivering that result from dose dependent anesthetics. He also discussed the link between hypothermia and serious outcomes like SSI that have resulted in the maintenance of normothermia becoming a standard of practice. This article is a summary of multiple research studies he participated in that confirmed the causal link between hypothermia and serious outcomes like SSIs, raising the awareness of anesthetic triggered hypothermia (Cudahy, 2013).

In September of 2001, a study led by Andrew Melling involving preoperative warming was performed to analyze the effects of prewarming on the incidence of wound infection. This randomized control trial involved patients having clean surgery (breast, vein, or hernia). The group was divided into three groups. One group of 139 patients received prewarming for 30 minutes, one group of 138 patients received localized prewarming to the operative area only with a noncontact radiant heat dressing, and the control group of 139 patients did not receive prewarming at all. Patients were followed up at two and six weeks to determine if wound infections developed. The control group had an infection rate of 14% and the prewarmed groups, both local dressing and systemic prewarming, experienced an infection rate of only 5% (Melling, Baqar, Scott, & Leaper, 2001).

A randomized clinical trial was conducted in the United Kingdom and published in 2007 with the purpose of investigating the impact of prewarming on postoperative morbidity. Researchers utilized a conductive carbon polymer mattress to prewarm 47 patients for two hours prior to and two hours after surgery. The control group consisting of 56 patients did not receive prewarming of any sort. Patients were undergoing open abdominal colon resections. Prewarmed patients experienced a significantly higher temperature during the first 90 minutes of surgery. Results of the study revealed a reduction in surgical site infection from 27 – 13% in the prewarmed group with an overall complication rate reduction from 54 to 32% (Wong, Kumar, Bohra, Whetter, & Leaper, 2007).

In her 2008 article, noted hypothermia researcher Andrea Kurz wrote about the importance of platelet plug formation in initiation of the first and possibly second stage of wound healing. She proposed that growth and chemotactic factors are released by activated platelets. Hypothermia-induced coagulopathy impairs platelet function and therefore wound healing. She also discussed the effect of vasoconstriction-induced tissue hypoxia on scar formation as lack of oxygen reduces the tensile strength of collagen strands and subsequent wound healing (Kurz, 2008, pp. 50-51). She supports prewarming for 30 minutes preop to increase peripheral tissue heat content more than what will be lost due to anesthesia (Kurz, 2008, p. 56).

Identified Risk Factors for Hypothermia

In 2010, the American Society of PeriAnesthesia Nurses (ASPAN) published the second edition of their Evidence-Based Clinical Practice Guideline for the Promotion of Perioperative Normothermia. By this time, there was national recognition for the need to prevent intraoperative hypothermia. ASPAN assembled a team of 11 multi-disciplinary experts to systematically review and analyze published evidence regarding revisions to their 2001 Perioperative Normothermia Guideline. Components of the 2010 Guideline included risk factors for hypothermia, temperature measurement, preoperative, intraoperative, and postoperative patient assessment and management recommendations. Further research indications were also identified. For the purpose of this thesis, preoperative assessment and management recommendations are referenced. All of the recommendations are ranked by the quality and strength of evidence using a one to three scale based on the clinical indication of the recommendation and consideration of its risk versus benefit (Hooper et al., 2010).

A study performed by Certified Registered Nurse Anesthetists (CRNAs) in 2010 explored hypothermia in relation to known clinical variables. This study involved 287 surgical patients. The variables included type of anesthetic, length and type of surgery, ambient operating room (OR) temperature, patient age, warming devices, and the patient’s temperature preop, intraop, and postop. Patients were from 16 to 97 years of age; the average ambient OR temperature was 65° F; the mean preop temperature was 36.6 ° C; the mean postop temp was 36.8° C; and all types of anesthesia were utilized. Warming devices were used in 96.2% of the cases and hypothermia occurred in only 4% of the sample which was much less than studies 20 years prior. Because of the low incidence of hypothermia in the sample, discussion of the variables was not possible. Adherence to the new ASPAN algorithms and heightened awareness of the need to prevent hypothermia were thought to have resulted in such a low occurrence percentage (Burns et al., 2010).

A study conducted in 2010 compared oral and temporal artery temperatures preop, bladder temperatures intraop, and temporal artery and bladder temperatures after surgery for accuracy. Researchers concluded that the temporal artery thermometer did not correlate with the bladder thermometer for accuracy and should not be relied upon for core temperature comparison. Researchers in this study also looked at factors that increased the risk for unplanned hypothermia. They found that in this study of 48 patients, increased age, lower body mass index, and ambient OR temperature lower than 68° F were risk factors for hypothermia despite the use of forced-air warming intraop. Pre-warming was not utilized preoperatively in this setting (Winslow et al., 2012).

An Australian retrospective study conducted in 2010 – 2011, described the incidence of hypothermia in patients undergoing major colorectal surgery. The sample group of 255 cases was actively warmed intraop, but not preop. Results of the this study indicated that elective patients experienced the greatest drop in temperature between arrival to preop and commencement of surgery and patients greater than age 70 years were more at risk for hypothermia. Recommendations from the study included optimization of core temperatures prior to surgery to 36.5 º C or greater with both active and passive warming measures (pre-warming) especially for those over age 70 years (Mehta & Barclay, 2014, p. 555).

Prewarming Methods

In 1998, Operating Room (OR) and Post Anesthesia Care Unit (PACU) nurses conducted a study of 502 patients. In this study, forced air warming blankets were applied in the OR only at the discretion of the Anesthesiologist and in PACU if the patient was 35º C or less; otherwise warm cotton blankets were the primary method of rewarming. Sixty percent of the patients not treated with forced air warming in the OR were hypothermic on arrival to PACU. Results of this study indicated that forced air warming was more effective than other warming methods in the OR and PACU. This PACU also changed their standard of applying forced air warming to patients with a temp of 36º C or below. Also worth noting, hypothermic patients had a longer length of stay in PACU (Defina & Lincoln, 1998).

One of the earliest studies involving preoperative prewarming was conducted by PACU nurses at the University of California Surgery Center in Sacramento. One hundred patients were divided into two groups in which one group received prewarming and the control group did not. Participants in the prewarming group had statistically significant higher Preop and PACU arrival, as well as mean temperatures. Patients in the prewarming group ranked their thermal comfort higher than did the control group (Fossum et al., 2001).

A randomized controlled trial in Hong Kong compared forced air warming with the use of an electric heating pad. This study involved 60 patients having laparotomy. Warming occurred in the OR utilizing the Operatherm Electric Heating Pad which was placed under a gel pad and blanket on the OR table with 30 patients. The patient was placed on top of this warming apparatus. Thirty patients were warmed in the OR with a forced-air warming blanket. Results of the study were in favor of the forced air warming blanket in regards to effectiveness of maintaining core body temperature. Limitations of this study included absence of a control group (Leung, Lai, & Wu, 2007).

A research study in 2010 conducted by De Witte, Demeyer, and Vandemaele compared prewarming for 30 minutes with a forced air warming blanket system with a reusable carbon fiber whole body cover referred to as resistive heating. This was a small study of 27 patients undergoing elective laparoscopic colorectal surgery. The participants were placed in three groups of nine: control group, resistive warming group, and forced air warming group. Esophageal temperature probes were utilized during surgery and revealed that redistribution of heat was partially prevented by 30 minutes of prewarming with both the carbon fiber cover and the forced-air warming blanket. Core temperatures did not fall below 36° C in either treatment group. The conclusion of the study was that hypothermia can be prevented with 30 minutes of prewarming using either method (De Witte Demeyer, & Vandemaele, 2010, p. 832).

A study published in 2010 conducted by OR nurses involved three groups of patients having laparoscopic cholecystectomy. Trial 1was the control group receiving warm cotton blankets only; Trial 2 received only warmed irrigation fluids intraop; Trial 3 received forced-air warming preoperatively, intraoperatively, and postoperatively. There were 28 patients in each group aged 18 to 45. Trial group 3 attained the best results with 75% of the population achieving a temperature of 36° C or higher within 15 minutes of leaving the OR. A follow-up study was conducted six months later with 28 patients from all surgical types who received forced-air warming preop, intraop, and postop. One hundred percent of this population maintained a postop temp of 36° C within 15 minutes of leaving the OR. Researchers concluded that even during shorter procedures, patients can become hypothermic and therefore all patients should receive forced-air warming to promote normothermia (Lynch et al., 2010, p. 561).

An Australian study looked at the best temperature on the warming device to begin prewarming from the patient's perception of thermal comfort. Volunteers were utilized in this cross over design study and were asked to change from street clothes into a patient gown. They were seated in recliners and had a forced-air warming blanket placed over them. Two protocols were tested with application goals of 60 minutes for each group using the highest settings for the longest period. In Protocol A, the warming unit was placed at the highest setting of 43° C with the fan on high. The device temperature and fan speed were lowered if the volunteer complained of feeling too warm. Assessments occurred at 15 minute intervals. Protocol B involved starting the warming device at the lowest setting of 38° C and low fan speed. In this group, the settings were titrated up at 15 minute intervals and participants monitored for thermal comfort. After 24 hours, participants came back and participated in the opposite treatment group. Findings from this study indicated that participants preferred beginning with the higher settings of Protocol A by 70% as compared to 30% for Protocol B. Protocol A was well tolerated by awake participants. Researchers found that ratings of thermal discomfort and reports of sweating should guide titration of settings rather than temperature readings (Cobbe et al., 2012, p. 26)

This study is significant as it applies to the barrier of temperature monitoring in the preoperative setting after application of prewarming.

Prewarming Time Frames

Researchers in Britain performed a randomized clinical trial involving 68 patients, in which 31 were prewarmed and 37 patients were placed in a control group without prewarming. All were undergoing spine surgery. Results of the study indicated that prewarming was effective in 68% of the prewarmed group with maintenance of core temperatures above 36° C ($p \leq 0.05$). Researchers concluded that prewarming conducted for 60 minutes using a forced air warming gown was the ideal method and time period to reduce peripheral redistribution of heat in their population of patients undergoing spine surgery. It was noted by researchers that prewarming over too long a period of time can contribute to a potential increase in preop core temperature which can result in perspiration and a feeling of being too warm (Andrzejowski, Hoyle, Eapen, & Turnbull, 2008).

A German study published in 2010 involved 127 patients who were prewarmed before surgery on average 38 – 46 minutes during which time the patient's temperature rose to 37.1 ± 0.5° C and decreased after induction of anesthesia to 36.3 ± 0.5° C. Core temperatures at the end of the procedures were 36.4± 0.5° C with an occurrence of hypothermia intraop in only 14% of the sample. Researchers concluded that prewarming was possible and highly effective even when performed for brief periods in the prevention of hypothermia (Brauer et al., 2010).

A Brazilian study published in 2012 embraced the aims of research analysis on the effectiveness of prewarming in preventing hypothermia and the identification of knowledge gaps for future research on perioperative hypothermia prevention. Fourteen studies were selected for analysis. Study conclusions supported the use of prewarming to prevent hypothermia as well as identification of an effective prewarming time of 30 – 60 minutes to reduce hypothermia intraop. They identified an area of future research, carbon fiber technology as a method for pre-warming. Authors proposed that nurses can use this study to guide decision making regarding a prewarming program in the perioperative period (Poveda, Clark, & Galvao, 2012, p. 916).

A United Kingdom randomized clinical trial focused on the performance of different durations of active pre-warming in the preoperative setting. The sample included 200 patients having surgery with general anesthesia. Pre-warming was studied in three separate time frames: 10 minutes, 20 minutes, and 30 minutes. The control group was not pre-warmed. Results of this study were significant in that the control group had a hypothermia rate of 69%. Patients pre-warmed for 10 minutes had a hypothermia rate of 13%, 20 minutes of pre-warming resulted in a rate of 7%, and the group pre-warmed for 30 minutes had a rate of 6%. The conclusion of this study is that pre-warming for only 10 – 20 minutes mostly prevents hypothermia and reduces shivering at the end of anesthesia. This study is pertinent to clinical practice as application of pre-warming appears to be effective even for brief periods. Also noted by researchers is that forced-air warming started in the OR after induction of anesthesia does not reverse or prevent further hypothermia. Statistical significance was reached in this clinical trial with $P < 0.05$. Statistical analysis was conducted with t-tests and chi-squared tests. (Horn et al., 2012).

Pediatric Population Trials

A Canadian retrospective study was conducted with the aim of examining the effect of prewarming on the prevention of hypothermia in pediatric patients undergoing spine deformity corrective procedures. The goal at the authors' institution British Columbia Children's Hospital was to minimize the amount of time the patient was hypothermic during the case to 25% or less. There were two reasons for the study, one of which was to look at the occurrence and extent of hypothermia during this type of procedure in the pediatric population. The second reason was to evaluate prewarming on the outcome of hypothermia by retrospectively examining cases prior to the implementation of prewarming and postimplementation. Data was extracted between November 2009 and June 2010 preimplementation of prewarming from 88 cases. Postimplementation data was extracted between November 2011 and June 2012 from 105 records. Conclusions from this study confirm that prewarming with forced-air warming blankets significantly reduced the time of hypothermia during the surgical case. Another conclusion relative to clinical practice is that of not using the PACU temperature as the "point prevalence of hypothermia… as it does not capture episodes of and duration of intraoperative hypothermia" (Gorges, Ansermino, & Whyte, 2013, p. 1058).

Temperature Measurement Method Comparison

A retrospective study of 149 charts was conducted to assess the effectiveness of prewarming in preventing hypothermia throughout the perioperative period. The study was conducted over a period of two years ending in 2009. Patients undergoing colorectal surgery were prewarmed for one hour using a forced-air warming gown. Core temperature was assessed with a tympanic thermometer preop and upon arrival in the post anesthesia care unit (PACU). Hypothermia occurred in 48.6% of patients who were not prewarmed. In the prewarmed group, hypothermia occurred in only 11.69% of cases. Researchers concluded that prewarming was an important intervention to reduce hypothermia (Hooven, 2011, pp. 12-13). Drawbacks to this study included use of a controversial thermometer. The tympanic artery thermometer is not seen as accurate for estimating core temperatures. Also there is no mention of intraop temperatures in this study.

Researchers in Sweden conducted a randomized clinical trial of 43 patients undergoing colorectal surgery to determine which temperature measurement device was more accurate for determining core temperature during anesthesia. Unlike other studies, both the esophageal temperature probe and the nasopharyngeal temperature probe were inserted on each patient with measurements recorded for comparison. Results of this study indicated that the esophageal temperature probe detected changes in core temperature when the nasopharyngeal probe did not. In this study, prewarming occurred in the operating room prior to anesthesia and epidural insertion. Research conclusions also included confirmation that prewarming has a positive effect on core temperatures (Erdling & Johansson, 2015, p. 105).

Summary

According to the literature, perioperative hypothermia negatively impacts wound healing by impairing platelet function which in and of itself interrupts the release of growth and chemotactic factors needed for wound healing. Hypothermia produces vasoconstriction which reduces oxygen tension in the wound, which also interferes with collagen strand and scar development. When oxygen tension in the wound is reduced to

40-50 mm Hg, the chance of wound infection rises as neutrophil and macrophage function is impaired reducing the body's ability to fight invading bacteria (Kurz et al., 1996).

Additional findings from the literature review included the documented positive impact of maintaining perioperative normothermia in preventing complications. Gaps in research include the time and method for prewarming and consistent temperature monitoring methods intraop as well as postop. There is debate as to how long prewarming is necessary to be effective. The researcher noted variations from 30 minutes to 120 minutes. There are at least six different styles of forced air warming devices and blankets on the market. In addition there are also other types of prewarming devices which have not been fully investigated. These include a carbon fiber warming blanket, a conductive fabric blanket and mattress pad, as well as mattress pads that circulate warm water. Identification of risk factors for the development of hypothermia have not been definitively established with age, reduced body mass index, length of surgery, type of surgery, as well as gender all being mentioned in the literature. There is still much to be learned about preventing perioperative hypothermia.

The literature review includes documentation and support that maintaining perioperative normothermia prevents wound infection and other surgical complications. Discussion of the benefits of prewarming in preventing hypothermia from anesthetic triggered core to peripheral redistribution of body heat is the basis for the researcher's thesis. The continued occurrence of SSIs in elective surgical cases and the identified gaps in research validated the need to further investigate prewarming.

CHAPTER III

Methodology

Surgical site infection is a serious complication of surgery that impacts mortality as well as morbidity for the patient. Preventing SSIs must be a safety and quality priority for organizations (Fencl et al., 2015, p. 28). Research supports perioperative hypothermia as a risk factor for the development of SSI (Kurz et al., 1996; Melling et al., 2001; Kurz, 2008; Cudahy, 2013). The ASPAN Evidence–Based Clinical Practice Guideline for the Promotion of Perioperative Normothermia should be sufficient to guide nursing practice; however, barriers to implementation of prewarming continue to prevail (Hooper et al., 2010). The purpose of this research was to study the effectiveness of prewarming in the prevention of perioperative hypothermia in the spine fusion population.

Design and Implementation

The researcher utilized a retrospective chart review to compare spine fusion patients who received prewarming with spine fusion patients who did not receive prewarming for the occurrence of intraop hypothermia based on the core temperature measurements documented by the Certified Registered Nurse Anesthetist (CRNA) administering anesthesia during the case. Core temperature was monitored every five minutes intraoperatively and automatically captured in the electronic anesthesia record.

Setting

The retrospective study was conducted on records of patients who had experienced surgery in the Surgical Services Department of a large regional referral tertiary hospital in Western North Carolina.

Sample

A convenience sample of 889 patients was obtained from the Spine Surgical Data Base. Power analysis (Cohen, 1992) with $\alpha \leq 0.05$ at a power of 0.80 estimated a required sample size of 64 patients per comparison group. Inclusion criteria for the sample were adult patients who underwent surgical spine fusion with ICD-9 codes of 81.02, 81.03, 81.04, 81.05, 81.06, 81.07, and 81.08 or their equivalent ICD-10 codes. Increased SSI rates had previously been noted in this type of population. Exclusion criteria included active infection, fever greater than 100.4 preop, and intraop core temperature measured by skin probe only.

Protection of Human Subjects

Permission to conduct the study was obtained through the university and hospital Institutional Review Boards. Participant codes were assigned to each case, as medical record numbers were removed in the data set and data collection tool; therefore, no identifying characteristics of sample members were included.

Instruments

A researcher developed tool was utilized to collect data for the study (Appendix A). The following data were included in the tool:

- Participant ID number
- Preoperative temperature
- Last intraoperative temperature
- First PACU temperature
- Was prewarming utilized

- Did hypothermia occur intraop and if so, how many minutes was the patient hypothermic (core temperature < 36° Celsius)
- Were other intraoperative warming measures utilized, i.e. fluid warmer, upper body warming blanket, lower body warming blanket

Data Collection and Analysis

Through retrospective chart review, data from the Surgical Spine data set was collected by the researcher and entered into an Excel spread sheet. The researcher-developed tool described above was utilized to narrow the available variables down to those pertinent to this study. Variables were coded and entered into the Statistical Package for the Social Sciences (SPSS) software. Utilizing descriptive statistics, data analysis was conducted involving the following variables: preop temperature (temp 1), hypothermic first temp in OR (adminhypo), minimum temperature, maximum temperature, last intraop temperature, average intraop temperature, intraop warming measures, first PACU temperature (PACU Temp C), hypothermic minutes (cold time minutes), and prewarming. Analysis of the equality of the means utilizing T-tests occurred. Cross tabulation of the variables of prewarming 2 and admhypo (intraop hypothermia on first OR temp) occurred followed by Chi-Square Testing. Lastly variables were analyzed for correlation using Pearson Correlation testing. Due to the absence of correlation among variables, regression testing was not conducted.

Summary

The prevention of perioperative hypothermia is recognized as an important initiative in the prevention of postoperative complications such as bleeding, wound infection, prolonged recovery from anesthetics, and patient discomfort. Preprocedure warming of the patient is an initiative that can be utilized to prevent intraop hypothermia although inconvenient for caregivers and patients as well as expensive for hospitals.

CHAPTER IV

Results

Preprocedure warming is supported in various studies as an effective intervention in reducing intraoperative hypothermia (Brauer et al., 2010). Prewarming the patient using a forced air warming unit was the most common method used to help reduce intraop hypothermia. Prewarming, however, has not been fully supported by caregivers due to the inconvenience of application and monitoring recommendations. Spine fusion cases are particularly vulnerable to hypothermia because of the time it takes to position the patient before incision to provide surgical access to the spine.

Sample Characteristics

The sample size of this study was 889 surgical spine fusion cases. Fifty-four cases were eliminated due to missing data resulting in a sample size of 835 for Crosstabulation analysis of the variables prewarmed and admhypo (first OR temp < 36° C). There were 102 cases that were prewarmed and 733 cases that were not (see Table 1).

Table 1

Sample Characteristics

Group I Prewarmed		Group 2 Not Prewarmed	
N - 102		N - 733	
% Hypothermic	37%	% Hypothermic	45%
% Normothermic	63%	% Normothermic	48%

Intraop temperature monitoring was obtained using an esophageal probe in 90% of cases and by nasopharyngeal probe in the remaining 10% of cases (see Table 2). Skin temperature monitoring cases were eliminated. PACU temperature monitoring occurred with oral, axillary, or tympanic methods.

Table 2

Temperature Monitoring Method Intraop

Temperature Monitoring Method Intraop

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Esophageal	800	90.0	90.0	90.0
	Nasopharyngeal	89	10.0	10.0	100.0
	Total	889	100.0	100.0	

The mean for minimum intraop temperature was 35.6° C and the mean for the variable maximum intraop temperature was 36.8° C. The mean for average intraop temperature was 36.2° C and the mean for last intraop temp was 36.7 ° C (see Figures 2, 3, 4, and 5).

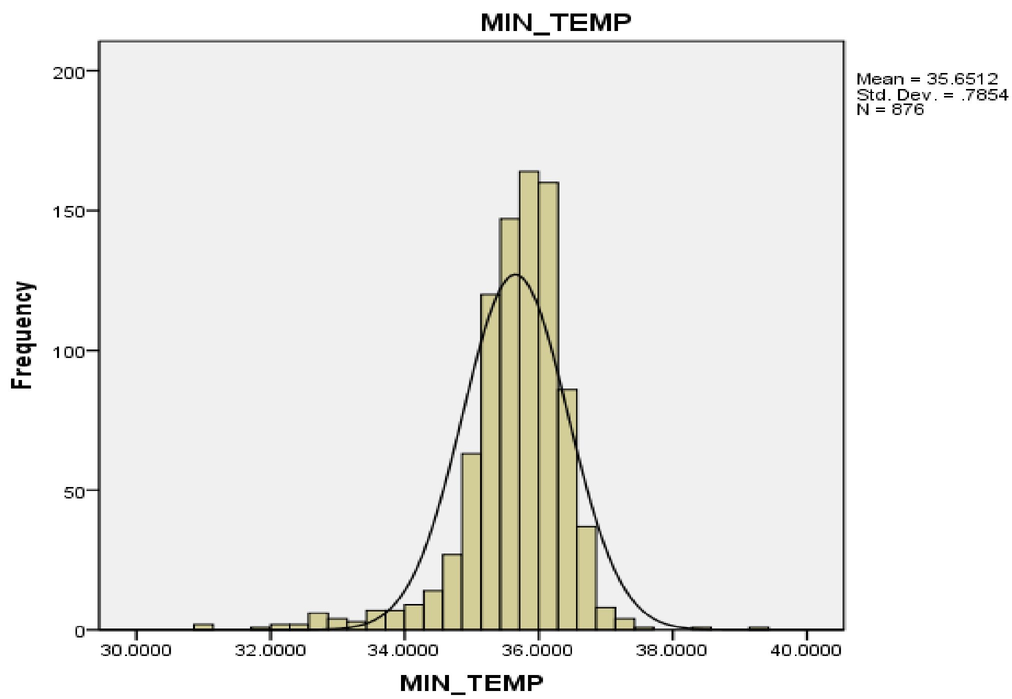

Figure 2. Minimum Intraop Temperature. The mean for minimum intraop temperature was 35.6° C with outliers to the left and right of the bell curve.

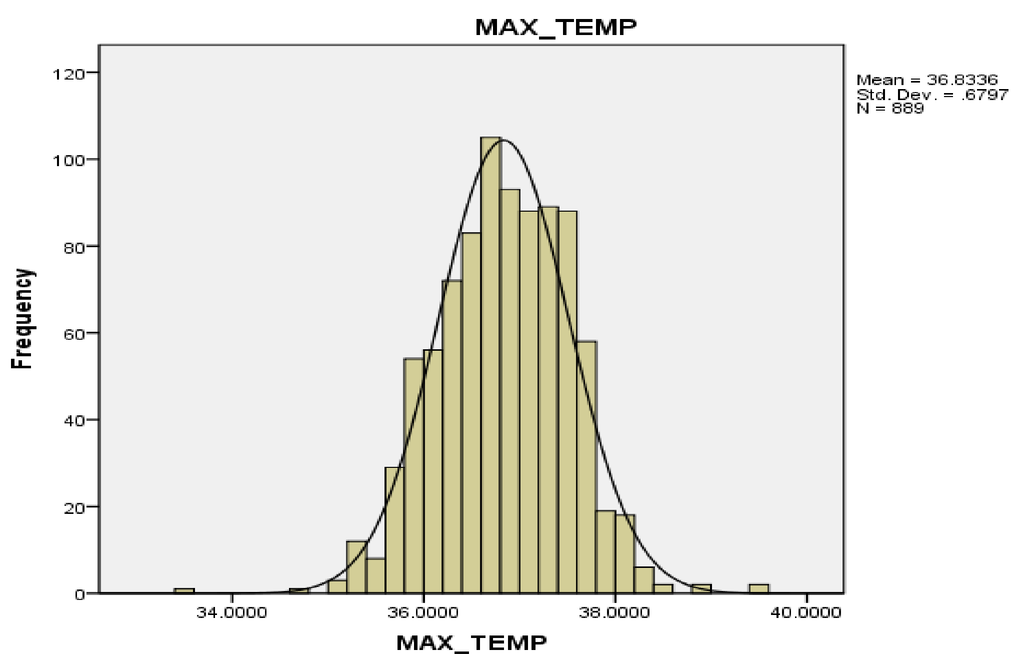

Figure 3. Maximum Intraop Temperature. The mean for the variable maximum intraop temperature was 36.8° C.

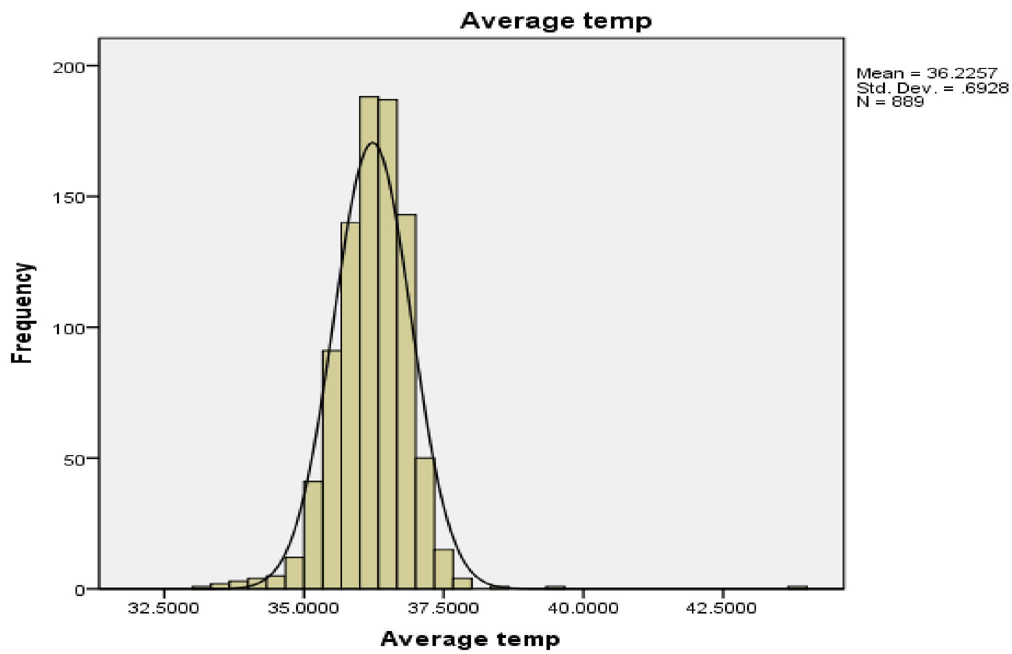

Figure 4. Average Intraop Temperature. The mean for average intraop temperature was 36.2° C with skewness noted to the left

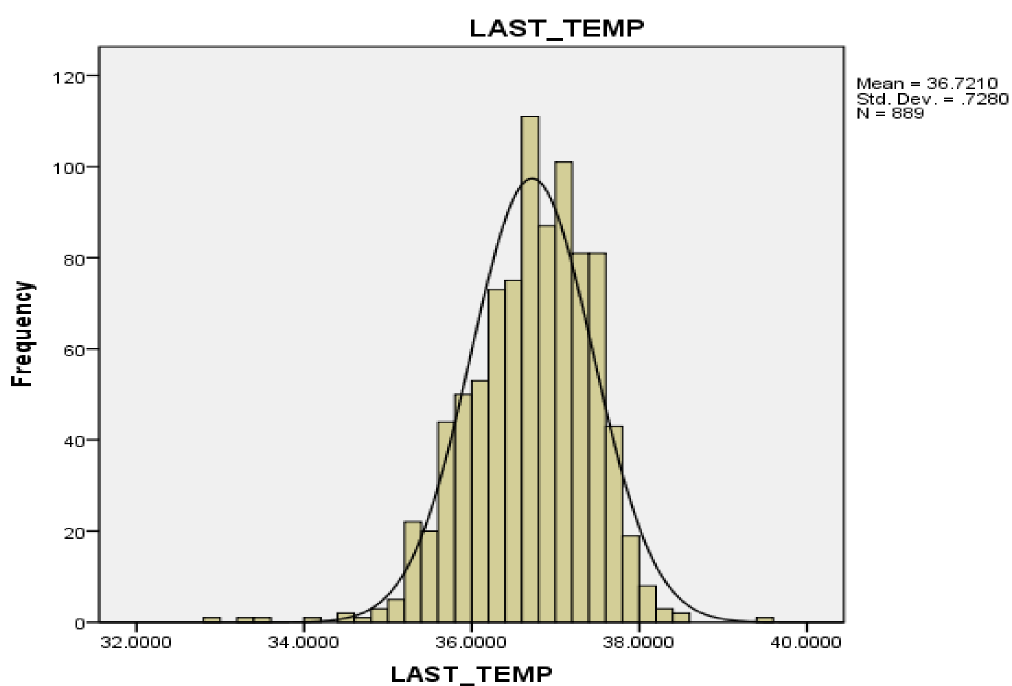

Figure 5. Last Intraop Temperature. The mean for last intraop temp was 36.7 ° C.

The variables of operating room time and surgery time were pertinent because of the time it took to position lumbar spine fusion cases into prone position with the head cradled in the supporting head rest to prevent optical damage and ensure positioning of the endotracheal tube after intubation. The time between arrival in OR to surgery start time can take 30 minutes or longer during which the patient was intubated, positioned, prepped, and draped. The intraop warming unit was not connected and turned on until after the patient was in prone position. The mean for surgery time was two hours 46 minutes compared to the mean for OR time which was three hours 42 minutes (see Table 3).

Table 3

Mean Operating Room and Surgery Times

	Surgery Time – surgery start to surgery end	Operating Room Time – in the OR to Out of the OR
Mean	02:46	03:42
Median	02:40	03:39

Intraop warming interventions involved the use of a forced air warming unit with upper body blanket, lower body blanket, and or an intravenous fluid warmer. At least one or all of these devices were utilized in all cases which was considered best practice (see Figure 6).

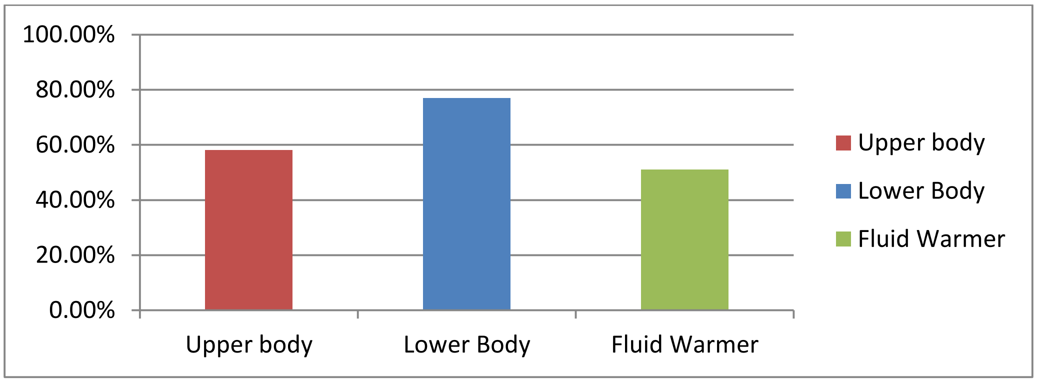

Figure 6. Intraoperative Warming Interventions utilized in all cases.

Major Findings

Cross tabulation analysis of the two variables prewarmed and admission to OR hypothermic revealed 63% of prewarmed cases remained normothermic (≥ 36° C) compared to 37% of prewarmed cases with a hypothermic temp (< 36° C) on arrival to the OR. Chi-Square tests did not support a significant correlation between the categorical variables of prewarmed and admission to OR hypothermic with $p > .05$ (Figure 7).

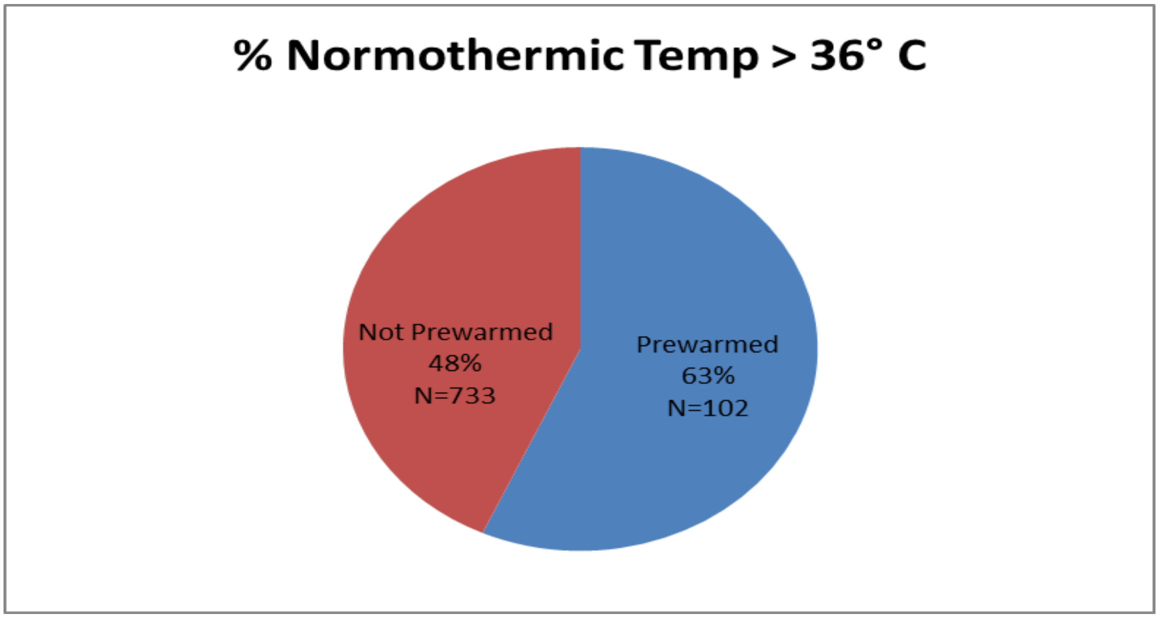

Figure 7. % Normothermia in Prewarmed vs Non-prewarmed Surgical Cases. This figure compared the 63% of patients who remained normothermic in the prewarmed group with the 48% of patients remaining normothermic in the non-prewarmed group. Prewarming increased the percentage of patients remaining normothermic by 15% in this study.

However, prewarming significantly impacted the variable cold time minutes. Cold time minutes in the prewarmed group had a mean of 24.76 minutes compared to the group that was not prewarmed which had a mean of 33.85 minutes. Levene's test for equality of variances revealed a significance of .050 (see Table 4).

Table 4

Relationship of Variables Cold Time Minutes and Prewarmed

Prewarmed & Cold Time Minutes		N	Mean	Std. deviation	Std. error Mean	Levene's test for equality of Variance
	Not Prewarmed	683	33.85	52.028	1.991	F = 3.838
	Prewarmed	93	24.76	48.967	5.078	Sig. = .050

The variable cold time minutes had a significant relationship to other variables as well. Table 5 lists the variables and their negative relationships to the variable cold time minutes including their two tailed significance values. (Table 5)

Table 5

Cold Time Minutes

Variables	Cold time Minutes	
PACU Temp	Pearson Correlation -.087	with Sig. of .015
Last Intraop Temp	Pearson Correlation -.183	with Sig. of .000
Max Temp	Pearson Correlation -.274	with Sig. of .000
Min Temp	Pearson Correlation -.499	with Sig. of .000

Summary

The research question was partially answered in the Cross tabulation study with the variable prewarmed having an impact on the variable hypothermic on admission to OR. Despite the lack of significance in Chi Square tests, 63% of prewarmed patients remained normothermic in the study. Subsequently, the variable prewarmed had an impact on the variable cold time minutes as illustrated in Table 4. Finally, by reducing cold time minutes (time in minutes the patient's intraop temp was < 36° C) the mean values for PACU temp, minimum temp, maximum temp, and last intraop temp were higher. If the patient had fewer cold time minutes, they were essentially warmer.

CHAPTER V

Discussion

Keeping surgical patients warm should be a major driver of practice change in the perioperative arena due to the numerous complications that can occur as a consequence of even mild hypothermia. The purpose of this retrospective research study was to investigate the effects of prewarming the patient prior to spine fusion surgery in an effort to prevent intraoperative hypothermia and/or reduce the time in minutes the patient's temperature dropped below 36° C. A literature review in 2012 supported the effectiveness of the combination of prewarming using a forced air warming device and continued intraop warming using forced air warming as well (Poveda, Clark, & Galvao, 2012, p. 45).

Implication of Findings

Fettes, Mulvaine, and Van Doren, 2013 urged nurses to consider the impact and consequence of the long term effects of hypothermia for the patient such as increased risk for wound infection as well as possible pressure ulcer development. Perioperative nurses must utilize critical thinking skills and implement best practice through consistent implementation of prewarming in order to prevent intraoperative hypothermia and its complications.

Application to Theoretical Framework

Betty Neuman's Systems Model proved to be an appropriate theoretical framework for the research study as she emphasized wellness and the need to incorporate preventive strategies to cope with harmful environmental stressors. The key to flexibility in applying her model to this study would be helping nurses educate patients in the purpose and need for prewarming so they remain open to wellness. One of the barriers to consistent application of prewarming is the patient's refusal to comply based on lack of information and their perception of comfort.

Limitations

The greatest limitation to the study involved a lack of understanding of purpose for the patient, application of the bulky prewarming blanket without patient control of temperature, and manufacturer recommendations to monitor temperature post application in Preop. Application of the blanket also limits patient movement and the warming unit is somewhat noisy when turned on. Prewarming was documented in only 102 cases, well above the 64 cases planned as a result of the power analysis, but was outranked by the 733 cases that were not prewarmed. This disparity may have skewed the results of the study limiting its generalizability.

Implications for Nursing

As a result of hearing about the research study, awareness of the need to prewarm patients has made an impact on Perioperative Leadership with their renewed support in consistent application of prewarming for future patients. After the study was completed, it was decided by leadership to apply prewarming blankets to all preop patients regardless of type of surgery they are scheduled for. Repeating the study after a few months of consistent application of prewarming may reveal an improved trend in prewarming and even further reduction in cold time minutes consistent with hypothermia.

Recommendation

Research and possible trial of new prewarming products such as the new reusable carbon fiber blanket would be beneficial in supporting compliance with application.

Repeating the study after a few months of consistent implementation of prewarming may reveal improved trends in reduced cold time minutes consistent with evidenced based best practice.

Conclusion

This study contributed to the body of knowledge regarding the need to prewarm patients to prevent perioperative hypothermia and its serious consequences. It also revealed the need for continued work in educating staff and patients in evidence-based practice initiatives. Sharing the results of this research study may help improve patient outcomes through prewarming.

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Appendix A

Research Data Collection Tool – Preprocedure Warming to Prevent Intraoperative Hypothermia

Data Collection Tool	
1. Participant Code	
2. Preop Temperature	_________ Celsius _________ Method
3. Last Intraoperative Temperature	_________ Celsius _________ Method
4. First PACU Temperature	_________ Celsius _________ Method
4. Was Prewarming Utilized	_________ Yes _________ No
5. Number of minutes intraop the patient was < 36° Celsius (Cold Time Minutes)	________ minutes < 36° Celsius
6. Duration of Case (OR Time)	________ minutes
7. Were other warming measures utilized intraop?	_________ Fluid Warmer _________ Upper Body Blanket _________ Lower Body Blanket