Comparing Patient Temperatures in Adults during Lower Spinal Surgery using either a Heated Ventilator Circuit or a Standard Ventilator Circuit with a Heat-Moisture Exchanger

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BACKGROUND:

Hypothermia is a core temperature less than 36°C in surgical patients,[1,2] affecting up to sixty-four percent.[3] All surgical patients are at increased risk as intrinsic thermoregulation is impaired by anesthetics' effects,[4-8] increasing the core temperature threshold from 0.2°C to 4°C; this delays normal compensatory mechanisms.[9,10] This effect is compounded by the cold surgical environment,[4,5,8,11] IV fluids,[4,5,12] and airway gases.[4,9,13] Hypothermia is known to have several deleterious complications.[10,14]

Surgical site infections occur more frequently,[15-17] as there is increased vasoconstriction near surgical wounds, which decreases oxygen and nutrient delivery.[9,16] Immune function also is impaired[9,18] from raised interleukin-6 levels[19] and damaged neutrophils.[4,9] Coagulopathies are more prevalent[9,11,20] because of impaired clotting cascade enzymes[11,20-22] and platelet function as well as increased fibrinolysis.[11,20,22] As a result, greater blood loss[11,14,23-25] and subsequent transfusions are observed,[16,17,23,24] up to 16% and 22%, respectively.[26] Colder patients experience increased cardiac-related events,[9,17,27,28] as norepinephrine levels can be 7-fold, [29] precipitating hypertension,[9,30] angina, and myocardial ischemia.[31] In addition, drug metabolism is decreased,[4,28] prolonging medication effects[22,32] and increasing potency.[2] Post-anesthesia shivering is more observed in hypothermic patients,[1,4,12,15-17,23,27,29,33-37] which can increase oxygen consumption,[12] with estimates 110% or greater.[29,35,38] Pressure ulcer formation[39] and greater postoperative pain[15,38] are further described. These events significantly impact surgical patients as there is increased time to extubation,[19] post-anesthesia recovery,[10,12,40] hospitalization,[3,16] and mortality.[4,11,28]

Heat is lost through radiation, convection, conduction, and evaporation,[2,5,11,12] with radiation and convection being the most significant sources.[6,9,33] Patients try to maintain

normothermia, defined by Hooper et al[41] as a core temperature between 36°C and 38°C. This mechanism, however, is disrupted through three phases during surgery.[6] Post-induction is the first phase, with anesthetics inducing vasodilation, even in response to cold-stressors; this abruptly shifts core heat peripherally,[6,36,42,43] as there is a decrease of 1-1.5°C within the first hour.[6,7] The second phase occurs over the next 1-2 hours[6,7,44] and is associated with a slow, linear heat loss as the heat deficit exceeds heat production.[6,33,44] Phase III occurs after three hours of induction[6,33,44] and is associated with a plateau state as peripheral vasoconstriction is triggered in an attempt to reestablish thermoregulation.[6,9,33,44]

The standards of practice for the American Society of Anesthesiologists and the American Association of Nurse Anesthetists recommend that patient temperature should be monitored and maintained when significant changes are anticipated or suspected.[45,46] This is also supported through the clinical practice guideline by the American Society of PeriAnesthesia Nurses, which states "frequent intraoperative temperature monitoring should be considered in all cases"[(p.353)] as well as proper assessment for hypothermia.[41] The Centers for Medicare and Medicaid Services (CMS) initiated the Surgical Care Improvement Project-Infection-10 (SCIP-Inf-10) in 2009 as means for maintaining normothermia in surgical patients undergoing general or neuraxial anesthesia for greater than one hour,[47] which was required for hospitals participating in CMS.[48] SCIP-Inf-10 applied reimbursement costs the following two ways[47]: 1) maintaining a patient's temperature at least 36°C within 30 minutes before or 15 minutes after anesthesia's end time or 2) attempting to maintain patient normothermia by active warming methods. SCIP-Inf-10 was retired January 1, 2014 as an active measure for The Joint Commission and CMS.[49] However, CMS in December 2014 as part of their "List of Measures under Consideration Table" included the normothermia outcome defined as the following to be addressed[50]: "This measure

evaluates whether patients having surgical procedures under general or neuraxial anesthesia of 60 minutes or more in duration are normothermic within 15 minutes of arrival in PACU."[(np)]

Achieving normothermia on arrival to the PACU is only a partial goal as deleterious effects can be potentiated intraoperative while seemingly corrected postoperative. Coagulation during surgery is dynamic as fluctuations according to patient temperature may or may not be noticed if the patient is normothermic in the PACU, even if they were hypothermic intraoperative.[11,20] Sun et al included over 58,000 patients in their study to evaluate temperature patterns perioperative, demonstrating approximately 50% and 20% of patients having temperatures less than 36°C and 35.5°C for over an hour, respectively.[3] Furthermore, 20% of these patients had temperatures less than 36°C for greater than two hours.[3]

Several interventions are commonly utilized to manage patients' temperatures intraoperative, such as blankets, circulating fluid mattresses,[2,36] forced air warming,[15,27,30,35,36,43] IV fluid warmers,[1,15,29,34,51] and heated breathing circuits.[13,23,37,51-56] The most used heating intervention is forced air warming as it is relatively inexpensive[3,5] and increasing ambient temperature isn't usually an option as the surgical staff can get too hot from their additional layers.[4,5,9] Maintaining normothermia can be challenging utilizing only forced air warming in certain populations, such as patients undergoing spinal surgery.[23] These patients are positioned prone and active warming is often delayed more than 30 minutes. Employing multiple active warming devices has been suggested in several studies and may be a viable option to prevent hypothermia from developing.

Less than 10% of heat loss occurs via the airway; although, this has been suggested as a possible location for warming patients.[9,13,33,52] Several studies have incorporated heated humidification as a warming method, but the results are conflicting regarding its effectiveness.

Some suggest no effects are achieved,[13,51,54,57] while others have demonstrated higher initial temperatures following induction[23,37,55] as well as maintaining these temperatures during surgery.[23,37,52,53,55,56] Heated humidifiers use active warming and are shown to be superior compared to heat-moisture exchangers (HMEs), which passively warm the airway.[37,52,58] Several studies have observed temperature changes of 0.5˚C or greater in patients provided active heat and humidification compared to patients given none or passive humidification.[13,23,37,52,55-57] A temperature difference of 0.5˚C has demonstrated clinical relevance, as patients have less intraoperative blood loss,[23,25,59] fewer transfusions,[23] decreased post-anesthesia recovery,[12,56] and less shivering.[12]

Most of the current literature regarding heated breathing circuits focuses on surgeries three hours or less, with small to medium patient populations, and healthier adults. This study will expand on the previous works by concentrating on surgeries greater than three hours and including less healthy adults. This will allow for evaluation of active heat and humidification in regards to patients experiencing Phase II and Phase III, as it is suggested that active heat and humidification would have an increased effect on temperature as surgery length progresses compared to patients receiving none or passive humidification.[23,37,52,53,55,56] The purpose of this study is to compare core temperatures in adult patients having lower spinal surgery for at least three hours in duration using either a heated ventilator circuit (ANAPOD™ Heat and Humidification System; Westmed) or a standard ventilator circuit with a HME (Thermovent® 600; Portex). The ANAPOD™ Heat and Humidification System (Westmed) provides active heat and humidification during anesthesia by warming inspiratory gases for intubated patients.[60] The HME connects between the endotracheal tube (ETT) and the standard ventilator circuit and is our hospital's standard practice for all spine surgery patients.

SPECIFIC OUTCOMES AND HYPOTHESIS:

The primary outcome of this study is to compare core body temperature four hours after induction in patients having lower spinal surgery, of at least three hours in duration and using either a heated ventilator circuit (treatment group) or a standard ventilator circuit with a HME (control group). For any patient surgery with a core temperature not reaching four hours post-induction, the final esophageal temperature will be used. We hypothesize that the treatment group will have higher statistically significant temperatures four hours after induction or using the last recorded esophageal temperature for surgeries not reaching that timeframe compared to the control group.

A secondary outcome will compare overall patient temperature trends between the two groups, perioperatively. We hypothesize that the treatment group will have higher statistically significant temperatures perioperatively 60 minutes post-induction compared to the control group. An additional secondary outcome will compare patient shivering between the two groups. We hypothesize that the treatment group will have less shivering compared to the control group.

MATERIALS AND METHODS:

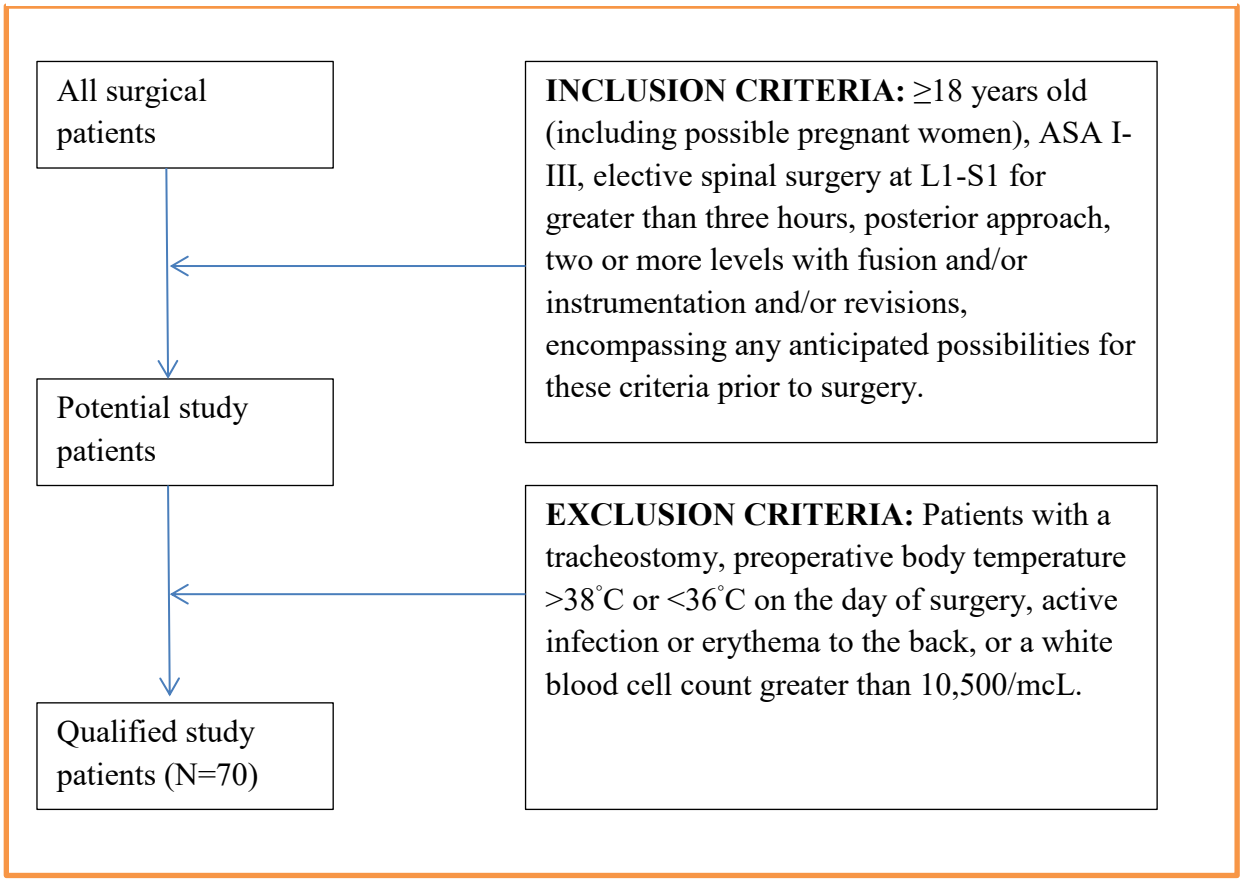
Following Institutional Review Board approval, a randomized, prospective study will be conducted on Saint Mary's Campus at Mayo Clinic Hospital in Rochester, MN. Study participants will be patients ≥18 years old (including possible pregnant women), with an ASA status of I-III, and the following surgery inclusive criteria: elective spinal surgery greater than three hours in duration, posterior approach, an operation site between lumbar one and sacral one, involving two or more levels with fusion and/or instrumentation and/or revisions, and encompassing any anticipated possibilities for these mentioned criteria prior to surgery. Exclusion criteria are the following: patients with a tracheostomy, preoperative body temperature

>38°C or <36°C on the day of surgery, active infection or erythema to the back, or white blood cell count greater than 10,500/mcL (Figure 1).

Patients will be randomly assigned to either the treatment group or the control group prior to surgery. Patients in the treatment group will be given heated and humidified inspiratory gases prior to being positioned prone following induction. Induction will be defined for this study as intubation since this will be the first opportunity to place an esophageal stethoscope with a temperature sensor as is the usual practice at our hospital. Distal esophageal temperature is a measure of patient core temperature[61,62] and has been demonstrated to not be affected by tracheal temperatures if placed correctly in the retrocardiac portion of the distal esophagus.[63-66] The retrocardiac position is represented by maximal heart sounds[66] or 38-42cm as measured from the central incisors in adults.[63] Education with anesthesia providers, incorporating visual aids and descriptive explanations, for placing the esophageal temperature probe at this location will be provided by a team member associated with this study prior to study enrollment. Even with proper education, this may be a study limitation if the probe isn't placed at the retrocardiac portion of the esophagus; however, this limitation should be minimized with the planned educational approach. All patients will receive a forced air warming blanket to their lower extremities and upper back at 43°C (high) after draping as is the usual practice at our hospital (Figure 2). If any patient has a temperature of 36°C for at least 15 minutes, both forced air warming controller devices will be turned off but remain in place under the drapes, as is the recommended practice at our hospital. If a patient's temperature decreases below 36°C, both forced air warming devices would again be turned on high setting (43°C). The operating room temperature will initially be set to 21°C by a team member associated with this study each morning prior to enrolled surgeries. The operating room temperature will be maintained at 20-

22°C, but may be adjusted beyond this range at the surgeon's discretion and/or subject's condition. The room temperature will be documented for all subsequent subjects every hour using an in-room digital display temperature device. It is important to standardize flow settings and tidal volumes as both may impact the amount of delivered heat to the patient, and it is recognized that these settings may be difficult to maintain during induction or patient positioning as higher volumes are generally given. The ventilator flow setting will be maintained at ≤2L/min or adjusted to meet the patient's needs during anesthetic maintenance, with tidal volumes 6-8ml/kg following patient positioning and induction. Patient randomization will assist with reducing any other potential sources of variation that may occur, such as patient exposure time during positioning.

FIGURE 1: Describes patient selection process



Patient's temperature will be measured and recorded in the preoperative area at least once prior to entering the OR suite. Intraoperative, patient's temperature will be measured and recorded within ten minutes or the first stable temperature reading after induction to establish a baseline. To allow for patient repositioning, the next temperature will be recorded within 30 minutes of the baseline esophageal temperature and every 10 minutes thereafter for the first hour post-induction, followed subsequently every 30 minutes until the patient is repositioned supine. Following the surgery, the patient will be transferred to the PACU, where the temperature will be measured and recorded at least once within 15 minutes of arrival (Figure 2). Oral temperatures (or axillary temperatures if an oral temperature cannot be obtained) will be used in the preoperative area, PACU, and ICU while esophageal temperatures will be measured in the OR suite after induction.

Patients will be monitored in the PACU for shivering as this can be an indicator of hypothermia. Any patients transferred directly to ICU from surgery will have a temperature recorded within 15 minutes of arrival. Any patient transferred to ICU will not be monitored for shivering. All patients' electronic medical records will be monitored through their hospital discharge, up to 30 days post-surgery to record any postoperative complications.

Shivering in the PACU will be assessed at least every 30 minutes for a maximum of two hours using the Bedside Shivering Assessment Scale (BSAS) described by Badjatia et al (Table 1).[67] This is a 4-point scale and rates shivering as the following[67]: absent, mild, moderate, or severe (Table 2). Absent means "no shivering noted on palpation of the masseter, neck, or chest wall."[67(p3243)] Mild means "shivering localized to the neck and/or thorax only."[67(p3243)] Moderate means "shivering involves gross movement of the upper extremities (in addition to

neck and thorax),"[p3243] and severe means "shivering involves gross movements of the trunk and upper and lower extremities."[67(p3243)] The BSAS demonstrated reliability among multiple users[67,68] and was tested for validity using indirect calorimetry (IDC) at rest.[67] IDC is often performed at rest and provides reliable, precise measurements of resting energy expenditure, which contribute largely to the total daily energy expenditure.[69] Nurses in the PACU will be educated to use this scale by a team member associated with this study.

FIGURE 2: Describes perioperative timeline and outcome measurement events

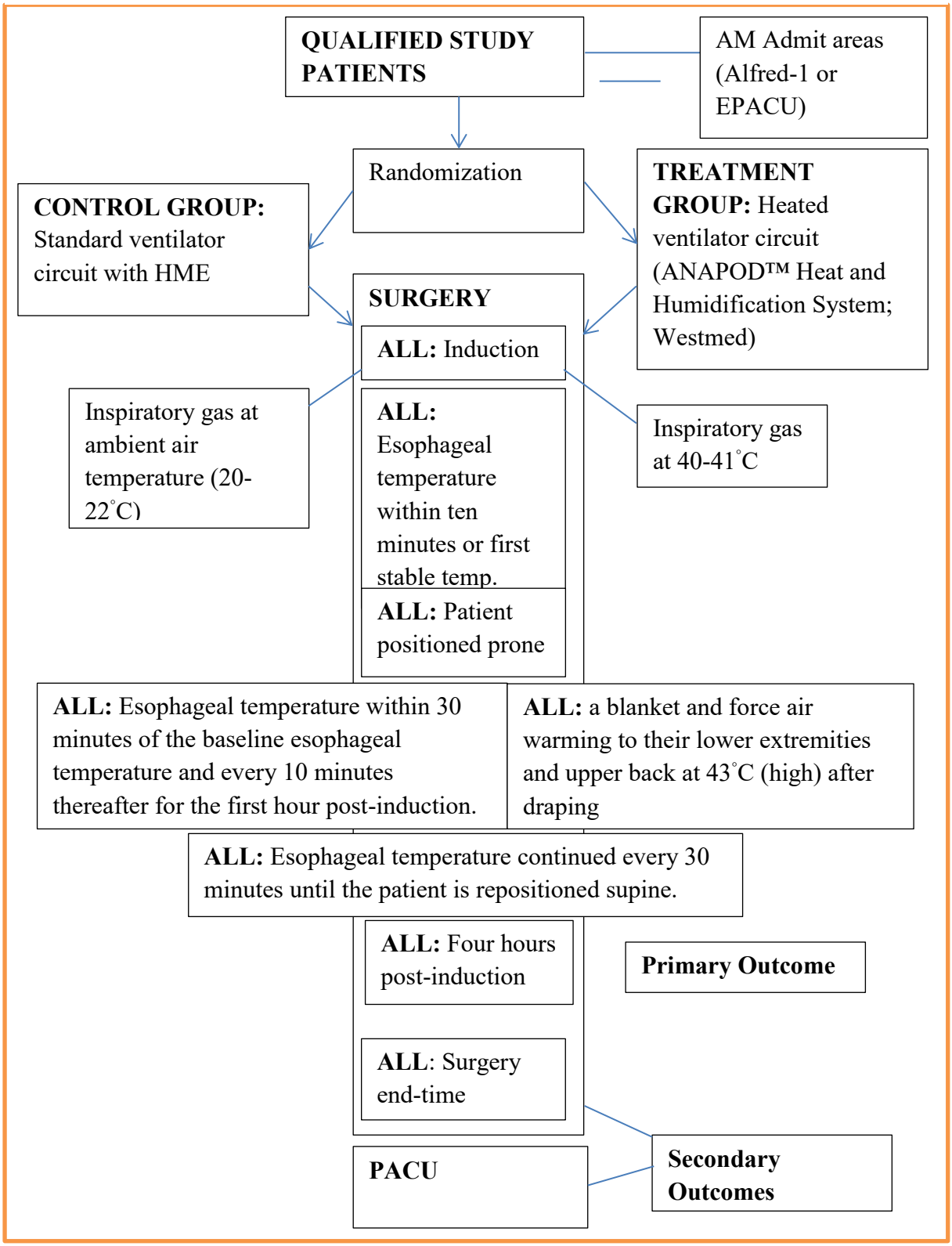


TABLE1: Describes study outcomes

OUTCOME	**LOCATION**	**DESCRIPTION**
Primary: Post-induction temperature	Intraoperative	Patient core temperature four hours post-induction or using the last recorded esophageal temperature for surgeries not reaching that timeframe compared to initial baseline esophageal temperature
Secondary Perioperative temperature	Intraoperative, postoperative	Patient temperature trends intraoperative to postoperative.
Shivering	Postoperative	Presence of shivering among patients in the PACU as described by Badjatia et al.[67] Assessed every 30 minutes for a maximum of two hours.

TABLE 2: Describes Bedside Shivering Assessment Scale developed by Badjatia et al.[67]

Score	**Definition**
0	None: no shivering noted on palpation of the masseter, neck, or chest wall
1	Mild: shivering localized to the neck and/or thorax only
2	Moderate: shivering involves gross movement of the upper extremities (in addition to the neck and thorax)
3	Severe: shivering involves gross movements of the trunk and upper and lower extremities

The ANAPOD™ Heat and Humidification System (Westmed) controller will be turned on prior to connecting the ventilator circuit to the ETT and will be set to 45°C with an acceptable fluctuation between 44-45.6°C. The temperature setting will be monitored and recorded every 30 minutes until extubation. This will be monitored by the anesthesia provider and documented in the patient's electronic medical record. The delivered temperature is expected to be 4-5°C less

than the administered temperature, which will provide airway gases at 40-41°C to patients in the treatment group.[70] If the patient's temperature is >37.4°C for at least 15 minutes using only the ANAPOD™ Heat and Humidification System (Westmed), then the controller unit would be turned off until the patient's temperature is <37°C, at which point the controller's temperature setting would follow the previous outlined parameters. The ventilator circuit associated with the ANAPOD™ Heat and Humidification System (Westmed) is comprised of a heated wick[70] and has a water trap on the expiratory limb to prevent humidity impacting the ventilator. A 0.5 micron hydrophobic filter (Smiths-Medical) will be placed at the patient-end of the gas sample line to prevent humidity impacting the gas analyzer. The ANAPOD™ Heat and Humidification System (Westmed) is a FDA approved device for all patient populations and uses sterile water for adding humidification to the ventilator circuit. This device has been approved by the Anesthesiology Equipment Committee and Anesthesia Biomed Department for this study. A team member associated with this study will provide education to anesthesia providers for using this equipment.

An investigator associated with this study will meet patients in the Preoperative Evaluation Clinic located at Gonda or the AM admit areas (on Alfred-1 or EPACU) located at St. Mary's campus. The investigator will review the consent form with patients meeting the study's eligibility requirements and enroll patients who are willing to provide written, informed consent. Patients will be randomized to the study after consent and enrollment as described in the section below.

STATISTICAL CONSIDERATIONS/ANALYSIS

Based on previous studies,[15,54] we anticipate the standard deviation of patient temperature is 0.6°C. Several studies have demonstrated that a 0.5°C temperature change is clinically relevant,

as patients have less intraoperative blood loss,[23,25,59] fewer transfusions,[23] decreased post-anesthesia recovery,[12,56] and less shivering.[12] Using the assumption that a standard deviation of patient temperature is 0.6°C and assuming that a difference between groups of 0.5°C is clinically relevant, we have determined that a total sample size of N=64 (N=32per group) will provide a statistical power (two-tailed, alpha=0.05) of 90% to detect a clinically relevant difference between groups. In order to account for potential attrition due to cancelled surgery, inability to place an esophageal stethoscope with a temperature sensor, and/or unexpected surgery length <3 hours, we propose a total sample size of N=70 (N=35 per group). Group randomization will be performed using a randomization schedule prepared by the Division of Clinical Statistics with subjects randomized in blocks of 4. This will ensure that after every 4th patient is enrolled, there are an equal number assigned to each treatment arm. Using this randomization schedule, individuals who will not have any subject contact for the present study will prepare randomization envelopes, which will be labeled according to subject ID number and contain an index card indicating the intervention assignment (control group or treatment group) for the given subject. For enrolled and consented patients on the day of surgery in the AM admit areas (Alfred-1 or EPACU), a subject will be assigned the next sequential subject ID number and the appropriate sealed envelope will be opened to reveal the subject's randomized intervention assignment. This will occur before the patient is transferred to the OR suite.

Data will be summarized using mean±SD (or median 25th, 75th) for continuous variables and frequency percentages for nominal variables. For the primary analysis, the esophageal temperature four hours post-induction or using the last recorded esophageal temperature for surgeries not reaching that timeframe will be compared between the control group and treatment group using analysis of covariance (ANCOVA) with pre-induction temperature included as a

covariate. This will account for any variation in pre-induction temperature, and the potential correlation between pre-induction temperature and the primary outcome temperature. In addition, a repeated measures analysis will be performed using all intraoperative esophageal temperatures recorded until surgery end-time, which will be defined as the last recorded esophageal temperature (for all patients). This analysis will be performed using mixed linear models with temperature as the dependent variable, time as a within subject effect, and treatment group as a between subject effect. Additional secondary outcomes will include shivering and temperature at PACU arrival. The frequency of any shivering during the PACU will each be compared between treatment groups using the chi-square test (or Fisher's exact test). Temperature at PACU arrival will be compared between groups using analysis of covariance (ANCOVA) as previously described. In all cases p-value ≤ 0.05 will be considered statistically significant.

FINANCIAL CONSIDERATIONS

Three ANAPOD™ Heat and Humidification System (Westmed) controllers will be provided by Westmed at no cost for the study's duration (David Christensen, Westmed Territory Sales Manager, email communication, January 21, 2015). Ventilator circuits for the duration of the study are $410.00 per case, and each case contains 20 individually packaged circuits (David Christensen, Westmed Territory Sales Manager, email communication, March 25, 2015). We plan to enroll 70 patients (35 patients for each arm), which requires two cases of ventilator circuits. The 0.5 micron hydrophobic filter is $108.85 per case, and each case contains 50 individually packaged filters (Pam Rasmussen, Mayo Clinic Surgical Process Analyst, email communication, April 30, 2015). One case will be required for the study. No staff education costs are expected, and all statistical analyses' costs will be provided at no charge using the Center for Clinical and Translational Science as provided to students. The current cost for a

standard ventilator circuit is $6.62 (Jean Guyer, Mayo Clinic Director of Nurse Anesthesia, email communication, March 12, 2015). Taking this into consideration, 35 standard ventilator circuits cost $231.70 and will be deducted from the cost analysis as these circuits will not be used. The total cost associated with this study is $697.15 ($928.85-$231.70) and will be supported by the Department of Anesthesiology.

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