Perioperative Hypothermia: Review for the Anesthesia Provider

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Abstract

Inadvertent hypothermia is a common occurrence with surgery which is detrimental to patients of all ages. Decreased core temperature activates several compensatory mechanisms to prevent damage. Temperature effects vary on different body systems. Certain populations are at higher risk for developing hypothermia and its deleterious effects. Characteristics of the operating room predispose a patient to hypothermia including effects of Anesthesia. Temperature measurement techniques vary by type and site of measurement. Pay for performance initiatives use normothothermia as a factor. Hypothermia is associated with adverse clinical complications such as myocardial ischemia, impaired coagulation, reduced resistance to infections, delayed wound healing, prolonged emergence, and increased recovery cost and time. Several strategies exist to maintain normothermia. Perioperative hypothermia is a preventable condition.

INTRODUCTION

Inadvertent hypothermia, a common occurrence within the surgical arena, poses detrimental consequences to patients of all ages. For the past few decades, researchers have been on a quest to discover the most cost-effective solution to thermoregulatory complications caused by both regional and general anesthesia. Although hypothermia has proven advantageous during cerebral and cardiac procedures, an overall decrease in body temperature can cause unfavorable effects on virtually all body systems.

DISCUSSION

NORMAL TEMPERATURE VARIATIONS

The human body is specifically engineered to maintain an adequate internal temperature. When its environment has been altered, the body enables mechanisms responsible for heat production or dissipation to achieve a more favorable temperature. In the average person, a normal circadian temperature variation of approximately 1 degree Celsius (C) exists from the average core temperature of 36-37 degrees C (1,2). Body temperature tends to fluctuate throughout the day, with its peak value in mid-afternoon and its minimum value occurring at around 3 o'clock in the morning (3). Hypothermia is characterized as at least 1 degree below normal core temperature (4,5). It usually manifests if there is a decrease in heat production, an increase in heat loss, or if thermoregulatory mechanisms become dysfunctional (5). In order for the body to maintain a state of homeostasis and function properly, heat production and heat loss must always be maintained at equilibrium.

NORMAL COMPENSATORY MECHANISMS

When the body experiences a decrease in core temperature, it employs several compensatory mechanisms in its attempts to prevent damaging effects. Body temperature is sensed by thermoreceptors that are activated at distinct temperature thresholds (6). The input obtained at these sensors is conveyed to the hypothalamus, the dominant thermoregulatory system in humans (7). The hypothalamus then initiates appropriate means to restore normothermia. Primary autonomic defenses against cold stress are arteriovenous shunt vasoconstriction (6,8) and shivering (5,6,8). The arteriovenous shunts are anastomoses that link arterioles and veins, and are mostly found on fingers and toes (2,6). They have a profound effect on core temperature by protecting it from significant peripheral tissue temperature changes. Vasoconstriction is characterized as an adrenergic response and works by decreasing cutaneous heat loss (9) and restricting metabolic heat to the core compartment (7). This mechanism prevents the decrease of an additional 1 degree C required to activate the shivering mechanism (7).

In most cases, heat loss is regulated without the body activating the shivering mechanism because vasoconstriction is usually sufficient to return core body temperature to necessary levels (7). Shivering is utilized by the body as a last resort (6,7), only activated when arteriovenous shunt vasoconstriction is inadequate to maintain core temperature (7). Postanesthesia shivering is frequently observed in patients undergoing emergence, and can be a serious complication if the patient has a compromised cardiopulmonary system (10). The mechanism of piloerection is also observed in hypothermic patients. By causing hairs throughout the body to become erect, it prevents air from escaping and aids in retention of heat (5). The three mechanisms of vasoconstriction, shivering, and piloerection are absolutely necessary to maintain an adequate internal temperature for the survival of vital organs.

TEMPERATURE EFFECTS OF BODY SYSTEMS

Many studies have been conducted to determine exactly what occurs in the body as a response to hypothermia. Though some effects may be beneficial in certain procedures, most result in destructive complications. Even mild perioperative hypothermia triples the risk of morbid myocardial outcomes (9), triples the risk of surgical wound infections (11), increases blood loss and transfusion requirements (12), and prolongs recovery and hospitalization(13).

NEUROLOGICAL SYSTEM

During neurosurgical procedures, the positives of hypothermia outweigh the negatives. Hypothermia serves as a form of protection in times of decreased cerebral blood flow because it reduces metabolic activity as well as the demand for oxygen and nutrients in cerebral tissue (5). Aerobic metabolism can then continue through these periods of compromised oxygen supply, reducing the production of anaerobic byproducts (14). In addition, there is decreased release of excitatory neurotransmitters, reduced synthesis of pro-inflammatory cytokines, and decreased apoptosis (15). Lastly, it lowers intracranial and cerebral fusion pressures (16).

Therapeutic hypothermia can offer significant protection against cerebral hypoxia and ischemia. On the other hand, a reduction in blood flow to cerebral structures has the potential to lead to irreversible neurological deficits, prolonged emergence, and increased recovery time.

CARDIOVASCULAR SYSTEM

Unintended hypothermia can result in adverse consequences to the cardiovascular system. As mentioned previously, the body reacts to hypothermia by producing vasoconstriction. As a result, enhanced resistance leads to increased blood pressure and myocardial afterload (5). This limits the ability of the myocardium to contract and prolongs signal conduction (17). A hypothermic patient may manifest with symptoms of hypertension (6) followed by compensatory bradycardia (6). Ventricular fibrillation and arrhythmias can also occur with significant hypothermia (9). In addition, when core temperature falls by more than 1 degree C, the body activates the shivering mechanism and places large demands on the cardiovascular system. Upon emergence in the early postoperative period, adrenergic and metabolic responses can interfere with the balance between oxygen supply and demand, potentially leading to ischemia and myocardial infarction (18).

Cardiac morbidity is the leading cause of death in the perioperative period (19). However, maintenance of normothermia throughout surgery has the potential of decreasing cardiac morbidity by 55% (9,20). A study by Frank et al showed a significantly greater incidence of postoperative hypoxemia, myocardial ischemia, and angina during the first 24 hours postoperatively in patients whose temperatures were less than 35 degrees C (18). The induced adrenergic response of the cardiovascular system to hypothermia is demonstrated by the cold pressor test (21), where a patient's hand is immersed in an ice cold bath (4 degrees Celsius) for approximately 2 minutes. The heart rate and blood pressure immediately increase, resulting from enhanced levels of circulating catecholamines like norepinephrine (21). Even mild hypothermia can trigger sympathetically mediated hypertension due to 100-700% increase of circulating norepinephrine (22). In addition, cortisol increases have a significant role in the response to cold stress and are associated with immune inhibition (23,24).

Hypothermia increases coronary vascular resistance and reduces coronary perfusion in patients, and can be detrimental in patients with heart disease (21). The effect on coronary blood flow provides insight into potential mechanisms of cold-induced cardiovascular morbidity in surgical patients.

HEMATOLOGICAL CHANGES

When the body's core temperature is depressed, the patient develops coagulopathy (2) and decreased platelet function (27,28). Blood loss is significantly increased with mild hypothermia, necessitating postoperative transfusions. Hypothermia has an effect on the kidneys as well, impairing the glomerular filtration rate and increasing blood urea nitrogen and creatinine levels (5). When undergoing surgical procedures, patients are at an even higher risk for blood clots due to hypothermia's enhancing effects on blood viscosity and peripheral vasculature resistance (5). The body experiences diminished blood flow to the extremities, which can lead to blood stasis, decreased perfusion to the vital organs, and postoperative deep vein thrombosis and pulmonary emboli (5). Hepatic and pancreatic functions are also reduced, lessening the efficacy of drug metabolism (5). As a result, anesthetic agents are metabolized more slowly, and the patient experiences longer emergence and enhanced recovery periods.

RESPIRATORY SYSTEM

The primary response of the respiratory system to hypothermia is hyperventilation that is followed by hypoventilation and abnormal breathing patterns (5). A decreased core body temperature leads to a leftward shift in the oxygen-hemoglobin dissociation curve (18), resulting in hemoglobin with a greater affinity for oxygen (25). The delivery of oxygen is therefore reduced, resulting in hypoxia, anaerobic metabolism, and lactic acidosis (26). The complications are worsened when the patient shivers due to the increased demand for oxygen and carbon dioxide production (7). Hypothermia also decreases bronchial arterial blood flow, which delays oxygen uptake and delivery to tissues (5). As oxygen exchange in the intrapulmonary system worsens, the body's compensatory mechanisms become inadequate, and patient decline is inevitable.

HIGH RISK PATIENT POPULATIONS

Throughout the patient population, many groups have a higher risk for developing hypothermia than others. For example, elderly patients have a significantly higher chance due to changes within the body as one ages (29). An elderly patient's metabolic activity and capability to thermoregulate is depressed due to decreases in muscle mass and adipose tissue (20). In addition, the elderly have decreased circulatory function with increased vascular stiffness (20), which interferes with heat distribution and autonomic influences on vasculature. Conduction abnormalities, hypertension, and bradyarrhythmias are much more prevalent in the elderly (29). Anesthesiologists must take these changes into consideration when caring for elderly patients undergoing surgery due to the increased risk of an adverse outcome. Infants, who have approximately three times the amount of body surface area to body mass ratio compared to adults, also have a high risk of developing hypothermia (5). Hypothermia is inversely related to amount of fat and the surface area to mass ratio (30). Infants are not able to utilize the shivering mechanism (6), and they are dependent on brown fat metabolism to normalize body temperature. Lastly, patients who have certain medical conditions may be predisposed to developing hypothermia. Patients with hypothyroidism or cardiac pathologies, in addition to burn, cachectic, and trauma patients, are just to name a few (5). Patients placed on certain medications, like anti-hypertensives and anti-psychotics, can also experience an offset in the essential equilibrium between heat production and loss (5). Acknowledging the patient populations that have an increased risk for developing hypothermia is essential in striving to maintain an adequate body temperature perioperatively.

Certain characteristics of the operating room can also predispose a patient to hypothermia. One major factor in the occurrence of lowered body temperature is a patient's exposure to the operating room's cold environment, which can range from 18-23 degrees Celsius. In most cases, this range of temperatures is for the comfort of the healthcare team with the appropriate amount of clothing, but the patient is often naked. In addition, the application of cold skin antiseptics, inhalation of cold anesthetic gases, and administration of cold solutions may be factors in the development of hypothermia within the patient (31). Moreover, surgery results in damage to the body, which can lead to a depressed postoperative immune response. The most serious complications of surgery with anesthesia are wound infections (32). Hypothermia impairs wound healing (9) and increases the risk for infections. The mechanism behind this complication is hypothermia's stimulation of vasoconstriction, which decreases oxygen, nutrient, and leukocyte delivery to the skin (33). In a study by Wenisch et al, the oxidative and phagocytic properties of neutrophils were significantly reduced as a result of hypothermia (32). Therefore, hypothermia impairs the body's natural ability to fight infection and extends recovery time.

EFFECTS OF ANESTHESIA

In addition to procedures and surgical environment, common general and regional anesthetics can increase a patient's risk for hypothermia. Certain anesthetic properties promote vasodilation and enhance the transfer of heat from the body's core to its periphery (34). Upon anesthetic induction, body temperature initially falls due to the internal distribution of heat from core to peripheral compartments and then temperatures continue to fall (0.5 to 1 degrees Celsius per hour (35,36) until a difference is established between heat production and loss to the environment. Below a certain temperature, vasoconstriction and reduced heat flow occur between peripheral and core circulation, causing reduced blood flow to the extremities (36). Vasoconstriction also depresses hepatic blood flow, resulting in impaired drug metabolism and prolonged emergence from anesthesia (5). Both general and regional anesthesia contribute to the development of hypothermia (4), so careful monitoring of temperature is required regardless of technique. All volatile anesthetics impair thermoregulatory mechanisms. Commonly administered agents with vasodilatory properties are propofol, morphine, and meperidine (6). Opioids are known to increase the normal thermoregulatory threshold range from approximately 0.2 degrees C to as much as 4 degrees C, rendering the patient unable to adjust core temperature due to excessive vasodilation (14). Due to the fact that in the elderly, diminished drug metabolism and anesthetic-induced inhibition of the thermoregulatory response is more severe, use of the lowest possible effective dosage/concentration of anesthetic agents is important.

RECOVERY

A patient's recovery time is affected significantly by lowered body temperature. Patients who have experienced perioperative hypothermia claim that postoperative shivering is uncomfortable and often less tolerable than surgical pain. Besides the discomfort associated with it, shivering has the potential to stretch surgical incisions (7), and increase intracranial (37) and intraocular pressures (38). Hypothermia is often associated with increased PACU admissions and prolonged hospital stays (36). In a study, two to five hours of care was necessary for patients to reach baseline, being highly dependent on the severity of the hypothermia and patient age (36). Extended recovery is potentially costly because postanesthesia charges are similar to those in the ICU. Since significant cost is associated with restoring patient's normothermic status, the benefits of reducing hypothermia in the OR will improve cost-effectiveness in the healthcare setting and enhance the quality of patient care.

TEMPERATURE MEASUREMENT

As a necessary precaution to reduce the deleterious effects of core hypothermia, perioperative body temperature monitoring has become routine within the OR. However, the site at which the temperature is obtained varies based on the healthcare provider's judgment. The three standard core temperature measurement sites are the pulmonary artery, nasopharynx, and distal esophagus (35,39). Less invasive methods can be achieved through oral, rectal, bladder, axillary, groin, skin, and tympanic membrane measurement (39-40). Yet, the most effective measurement of core body temperature is obtained by inserting the thermostat directly into arterial or central venous blood vessels (40). Obtaining measurements of an area with the same blood supply as the hypothalamus provides the most reliable core temperature (41). Given the proximity of the internal carotid artery to the tympanic membrane (TM), temperature can adequately represent true core temperature (41). However, this method remains controversial in its effectiveness because it is easily influenced by ambient room temperature. Whether the specific measurement site is limited by physiologic changes in blood flow or by environmental factors like ambient temperature, it is essential to find a site that is accessible, reliable, and consistently used on all members of the patient population.

When it comes to equipment used, electronic devices are currently more regularly used than mercury thermometers because they are a more accurate technology. A relatively new product is on the market called the infrared forehead skin thermometer (aka the temporal artery thermometer). The device is moved across the forehead until it rests over temporal artery (39,40). It has proven sufficiently accurate and considered an alternative method for temperature measurements in perioperative patients (42). Temperatures can also be measured by liquid crystal adhesive strips on skin (40). Any of these methods can be used to obtain temperature, but the variability achieved using different devices highlights the necessity to use consistent temperature device when obtaining clinical temperatures in patients.

PAY FOR PERFORMANCE

With all of the negative complications of hypothermia, a quality-based payment system was devised in order to provide initiatives for physicians to closely monitor temperature status in patients. The decision towards this action was motivated by the belief that improvements are necessary in overall medical care. The RAND Corporation conducted a study which documented that patients with relatively common conditions received optimal care less than 50 percent of the time (43). Within the past year, the

Centers for Medicare and Medicaid Services (CMS) implemented a final rule into the Surgical Care Improvement Project (SCIP) (44). SCIP -Inf-10 is the measurement of the proportion of patients, regardless of age, who received active warming to maintain perioperative normothermia. In addition, it encourages obtainment of at least one body temperature reading equal to 36 degrees C approximately 30 minutes before or 15 minutes immediately after emergence from anesthesia (44). These guidelines are meant to ensure appropriate patient care for patients undergoing surgeries of more than an hour. SCIP-Inf-10 also provides incentives for anesthesiologists to maintain normothermia throughout procedures. Clear indications of monitoring adequate core temperature are recommended by the National Institutes for Health and Clinical Excellence (NICE) guidelines for management of inadvertent hypothermia (45). The majority of the quality measures were developed in the American Medical Association’s Physician Consortium for Performance Improvement (46). The ASA, American Society of Anesthesiologists, proposed performance measures that were derived from evidence-based practice guidelines, especially those recognizing the anesthesiologist’s role in preventing nosocomial infections. (46) The proposed thermal management measure allows flexibility in physician judgment and can be met by active warming or achievement of target temperature (>36 degrees C) measured in the operating room or postanesthesia care unit.

METHODS TO MAINTAIN NORMOTHERMIA

The benefits of maintaining normothermia are undeniable when it comes to ensuring optimal patient care. Re-warming rates and heat transfer depend on patients’ metabolic heat production, initial core and ambient temperature, the effects of anesthesia and neuromuscular relaxants, and body surface area to mass ratio (49). The higher the patient’s body mass index (BMI), the higher the core body temperature (30). Therefore, obese patients require a shorter warming period with an active skin warming system compared to non-obese patients, especially in short duration surgery (30,36). Pre-warming, or increasing the total heat content of the body’s periphery before surgery, is an effective way of preventing intra-operative hypothermia in surgeries lasting less than one hour (47,48). A study showed that active pre-warming for 30 minutes prior to induction of general anesthesia warmed patients’ skin surface and minimized redistribution hypothermia (49). On the other hand, forced air warming (9,14) devices are implemented for surgeries that last more than one hour. Forced-air systems preserve normothermia most efficiently, even during the longest and most invasive surgical procedures.

Warmed cotton blankets, gel coated circulating mattress, electric heating pads, warmed intravenous fluid, heated and humidified gases have also proven effective in maintaining normothermia perioperatively (9,20,49). One study by Sellden et al concluded that amino acid administration can actually prevent anesthesia-induced hypothermia and reduce the incidence of wound infection while decreasing hospital stay (50). Amino acid infusions given before and/or during anesthesia and surgery reduced the incidence of hypothermia and shivering in patients on emergence and reduced time in the recovery room.

Looking at the bigger picture, it is indisputable that ambient temperature has significant influence on core hypothermia in the anesthetized patient. A room temperature of 21 degrees Celsius is the threshold below which the incidence of core hypothermia is significantly increased (18). Hypothermia is quite common at ambient temperatures of <21 degrees Celsius (29). At an operating room temperature of 23 degrees Celsius, hypothermia occurs less often (29). The study by El-Gamal et al demonstrated that a sufficiently warm ambient OR temperature was very effective in preventing hypothermia during general anesthesia. The risk of hypothermia was significantly reduced (only 10% of patients) with an ambient temperature of 26 degrees C 29). If the higher temperature can be tolerated by OR staff, keeping the room at 26 degrees C can enhance the effective maintenance of normothermia in surgical patients.

CONCLUSION

Perioperative hypothermia is a common, yet preventable, condition. It is associated with adverse clinical complications such as myocardial ischemia and cardiac morbidities, impaired coagulation, reduced resistance to infections and delayed wound healing, prolonged emergence, increased recovery, and postoperative shivering. With the detrimental effects of hypothermia on nearly all body systems, it is crucial that anesthesiologists continuously measure temperatures, and take precautions to maintain a stable body temperature throughout surgical procedures. Forced-air systems and increasing ambient temperatures in the operating room are just two methods that can significantly decrease the occurrence of hypothermia within the surgical arena. Increasing awareness about the beneficial effects associated with the maintenance of normothermia will prevent complications, and improve the quality and safety of anesthesia care for our patients.

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