Special Article

Inadvertent Perioperative Hypothermia: The Incidence, Risk Factors and Adverse Effects

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Abstract
Introduction: Body temperature is an important physiological index of the human body, and having a normal body temperature is necessary for maintaining homeostasis. Inadvertent perioperative hypothermia (IPH) is defined as a core body temperature less than 36°C.
Background: IPH in surgical patients is high and varies between 20-90%. Every patient undergoing surgery is at risk for IPH, some risk factors increase its occurrence. The factors that increase the risk of IPH in the surgical patient can be divided into patient-related and surgery-related risk factors. IPH is closely related to numerous adverse events such as disturbed drug metabolism, an increased risk of surgical site infection, coagulation dysfunction, post-operative ileus, postoperative cardiovascular events, increased bleeding risk, and consumption of red blood cells, prolonged hospitalization times, delaying of discharge from the post-anesthesia care unit, disruption of thermal comfort, pressure ulcer, and high medical expenses.
Conclusions: Determination of the risk factors of IPH may help to prevent IPH.

Keywords: Hypothermia, risk factors, adverse effects, incidence

Introduction

Body temperature is a vital sign, and maintaining a normal body temperature is necessary for normal physiological functioning. Humans, a species of warm-blooded animals, maintain a normal body temperature is around 36.5°C-37.3°C with deviations of 0.5°C-0.8° (Demirarslan 2017; Liu & Qi, 2021; Sari et al., 2021). Hypothermia, defined as the core temperature below 36°C, is a common problem among surgical patients and closely related to many adverse effects in patients such as cardiovascular diseases, impairment of drug metabolism, coagulation dysfunction, an increased risk of infection, prolonged hospitalization times, and high medical expenses. Patients maintained at normothermic during the perioperative period experienced fewer complications, thus reducing healthcare costs. (Liu & Qi, 2021; Sari, Aksoy & But, 2021; Yan et al., 2021).

Inadvertent perioperative hypothermia

Hypothermia is defined as a core body temperature below 36°C and is classified as mild (34°C-36 °C), moderate (32°C-34°C), and severe (<32°C) (Simegn et al., 2022). Since hypothermia can also be used for therapeutic purposes in surgery, the concept of "Inadvertent Perioperative Hypothermia

(IPH)" is used for hypothermia, which is generally encountered as an undesirable condition (Aygin & Yaman, 2019). IPH is the decrease in body temperature below 36°C (96.8°F) from the preoperative period (1 hour before anesthesia) to the postoperative period (first 24 hours after anesthesia) (Sahin Akboga, 2021; Inal et al., 2017; Russel et al., 2022).

IPH is a common occurrence due to core-to-peripheral redistribution of heat, anesthetic-related impaired thermoregulation, and exposure to a cold environment (Demirarslan, 2017; Keskin, 2021; Simegn et al., 2021). Anesthesia, by disrupting the functions of peripheral and central heat receptors, prevents the perception of temperature changes, impairs the function of the thermoregulatory center in the hypothalamus, decreases metabolic heat production, and increases heat loss by causing vasodilation in the vessels (Demirarslan, 2017; Prado et al., 2014). Therefore, many patients experience hypothermia during their surgical procedures (Akers et al., 2019).

Incidence of inadvertent perioperative hypothermia

The incidence of IPH in surgical patients is high and range from 20% to 90% depending on the type of surgery, method of anesthesia, patient's age, measurement site, and thermometer type used (Cho et al., 2021; Inal et al., 2017; Liu & Qi, 2021; Mendonca et al., 2021; Sari et al., 2021; Zhang et al., 2021). In a study, it was determined that 89% of the patients were normothermic in the preoperative period, 74.3% were hypothermic in the intraoperative period and 75.7% were hypothermic in the postoperative period (Vural et al., 2018). In another study conducted with patients undergoing abdominal surgery, the incidence of hypothermia in the postoperative period was 62.4% in 0th postop hour, 42.9% at 1st postop hour, 33.9% at 2nd postop hour, 22.2% at postop 3rd hour, and 13.2% at 4th postop hour (Aldemir et al., 2021). The incidence of intraoperative hypothermia in China is 44.3% in patients undergoing general anesthesia (Yi et al., 2017). Despite multiple warming methods available and advances in operating room technology, IPH remains a clinical problem prevalent.

Risk factors of inadvertent perioperative hypothermia

Every patient undergoing surgery is at risk for IPH, but some risk factors that increase its occurrence. The factors that increase the risk of IPH in the surgical patient can be divided into patient-related and surgery-related risk factors (Akers et al., 2019; Yuksel & Ugras, 2016).

Patient-related risk factors

Newborns or babies born with low birth weight: Preterm and low birth weight neonates are prone to hypothermia as their temperature regulation mechanism is immature (Aygin & Yaman, 2019; Hu et al., 2021; Tanigasalam et al., 2019).

Gender: Multiple studies have shown a significantly higher incidence of IPH in female patients. The incidence difference between the gender may be related to the effects of differences in BMI, muscle mass, fat mass distribution, and body surface area on the thermoregulation mechanism (Aygin & Yaman, 2019; Demirarslan, 2017; Prado et al., 2015).

Age: Studies show that older patients (more than 70 years old) are at greater risk for IPH (Akers et al., 2019; Billeter et al., 2014; Liu & Qi, 2021; Sari et al., 2021; Yan et al., 2021). The higher incidence of IPH in older adults may be related to the reduction in muscle mass and subcutaneous tissue, lower resting muscle tone, a larger body surface area to body weight ratio, a lower metabolic rate, slowing down of the functions of the hypothalamus, and nervous system which affects negatively the body heat production and retention and decreases thermoregulation (Akers et al., 2019; Prado et al., 2015; Yan et al., 2021). The absorption of nutrients used in heat production slows down due to the slowing down of gastrointestinal system activities in old age. Thermal insulation decreases due to thinning of the subcutaneous adipose tissue. The vascular response to temperature change is delayed due to the slowdown in the vasomotor reflex. Increasing secondary diseases and multiple drug use with aging affect heat production and distribution in the body. In addition, as the pharmacokinetics and pharmacodynamics of drugs slow down, the excretion of anesthetic

agents from the body slows down (Demirarslan, 2017; Inal et al., 2017).

Body Mass Index (BMI): The risk of hypothermia is increased in patients with BMI below 25 due to low subcutaneous adipose tissue and muscle mass (Aygin & Yaman, 2019; Duman & Yilmaz, 2016). Fat tissue of overweight patients has an isolating function and these patients have a higher vasoconstriction threshold (Emmert et al., 2018). Cachectic patients are at higher risk of hypothermia due to poor general condition, muscle atrophy, and potential anemia (Inal et al., 2017). Studies have reported that more hypothermia was observed in patients with low BMI (Aksu et al., 2014; Duman &Yilmaz, 2014). Zhang et al. (2021) determined that higher BMI was associated with decreased risk of postoperative hypothermia. In a national study by Yi et al. (2017) in China, it was determined that higher BMI (BMI ≥25) helps maintain intraoperative normothermia.

The American Society of Anesthesiologists (ASA) physical status classification: The risk of hypothermia increases in patients with an ASA score of II and above (Aldemir et al., 2021; Aygin & Yaman, 2019; Mendonca et al., 2021; Vural et al., 2018).

Systolic blood pressure: Patients with systolic blood pressure above 140 mmHg are at higher risk of hypothermia under anesthesia (Aygin & Yaman, 2019; Mendonca et al., 2021; The Turkish Anaesthesiology and Reanimation Society Guidelines, 2013).

Presence of disease other than surgical pathology/comorbidities: The hypothermia risk is higher in patients with heart disease, brain tumor, adrenal insufficiency, chronic kidney failure, diabetes, neurologic disorders, and anemia. Hypoglycemia and hypothyroidism increase the risk of hypothermia by causing a decrease in metabolic rate (Akers et al., 2019; Billeter et al., 2014; Inal et al., 2017; Mendonca et al., 2021; Yuksel & Ugras, 2016).

Trauma and burn patients: IPH is a common and preventable complication during burn surgery. Total burn surface area is an important risk factor for intraoperative hypothermia (Hu et al., 2021). Burn patients are at increased risk for hypothermia due to the profound hypermetabolic state they exhibit and the loss of the thermoregulatory role of the damaged skin (Mullhi et al., 2021). The core temperatures of trauma patients are usually low when they come to the emergency department and are usually not covered during triage and treatment (Gezer et al., 2019; Inal et al., 2017).

Alcohol abuse: Alcohol leads to hypothermia by inducing peripheral vasodilation and inhibiting plasma vasopressin release. In addition, chronic alcoholics tend to have a lower body weight due to fats mass reduction and lower body weight is a risk factor for hypothermia (Cho et al., 2021).

Surgery-related risk factors

Preoperative risk factors

Long-term fasting: Long fasting duration of patients for various reasons in the preoperative period is a significant protective factor for postoperative hypothermia. Prolonged fasting causes insulin resistance, loss of muscle mass, and negative nitrogen balance (Aygin & Yaman, 2019; Demirarslan, 2017; Zhang et al., 2021).

Low body temperature before surgery: The body temperature decreases due to anesthesia during surgery. Therefore, patients with a pre-existing low core temperature before arriving in the operating room are at higher risk for remaining hypothermic intra- and postoperatively (Aygin & Yaman, 2019; Cho et al., 2021; Mendonca et al., 2021; Rauch et al., 2021; Vural et al., 2018; Yi et al., 2017; Zhang et al., 2021). Risk factors for a pre-existing low core temperature include older age, low BMI, and diseases. Emergency patients are often accidentally hypothermic on hospital admission (Rauch et al., 2021). Also, insufficient clothing or clothing thickness, cold bed or transport vehicle, wet clothing and bedding, cold room, and administration of cold intravenous fluids and blood products increases the risk of hypothermia before surgery (Rauch et al., 2021; Yuksel & Ugras, 2016).

Medications: Some medications can affect body temperature. Antipsychotic drugs can reduce temperature, while antidepressants increase core temperature (Rauch et al., 2021).

Intraoperative risk factors

Cutting the skin: Exposure to the body cavity disrupts the heat insulation mechanism of the skin and increases heat loss (Demirarslan, 2017; Keskin, 2021).

The temperature of the operating room and operating table: The operating room temperature being lower than 23°C increases the risk of hypothermia. The cold operating room table causes an increase in heat loss through conduction. The temperature of the operating room affects both the effect of anesthetic drugs and the temperature of the fluids and tools to be used in the surgery (Aygin & Yaman, 2019; Demirarslan, 2017; Yuksel & Ugras, 2016). There are studies in the literature reporting a relationship between ambient temperature and the risk of hypothermia (Vural et al., 2018; Yi et al., 2017). In a study, it was determined that the frequency of hypothermia is 50% when the temperature of the operating room is 20^0C-23^0C, and this rate is 10% when the temperature is increased to 26^0C (El-gamal et al., 2000). In a national study in China, higher baseline core temperature was associated with decreased risk of hypothermia in patients undergoing general anesthesia (Yi et al., 2017).

Cold intravenous and irrigation fluids, blood and blood products, insufflation of cold gases: Unwarmed irrigation solution is absorbed into the systemic circulation and decreases body temperature (Cho et al., 2021). Therefore, intravenous un-warmed fluid increases the risk of hypothermia (Yi et al., 2015). In addition, the cold solutions used in skin preparation increase heat loss through evaporation (Aygin & Yaman, 2019; Bindu, Bindra & Rath, 2017). 1 unit cold RBC can decrease body temperature by 0.25°C-0.35°C (Bindu et al., 2017). Using warmed irrigation fluid has positive effects on the body temperature and thermal comfort of patients (Seok & Chon, 2019). In a study, it was determined that the use of warm irrigation fluid during transurethral resection of prostate surgery reduces the risk of perioperative hypothermia and shivering (Singh et al., 2014). In a study conducted with patients undergoing general anesthesia, administration of unwarmed fluids during surgery was identified as a risk factor for hypothermia (Sari et al., 2021).

Type of anesthesia: The IPH risk is higher in patients treated with combined regional and general anesthesia (The Turkish Anaesthesiology and Reanimation Society Guidelines, 2013). Both general and regional anesthesia impairs central thermoregulation, although the extent of impairment is less with regional anesthesia (Cho et al., 2021). Hypothermia during general anesthesia occurs from a combination of anesthetic-induced impaired thermoregulation (cause vasodilation, inhibit vasoconstriction, and reduce metabolic rate) and from exposure to a cold environment (Bindu et al., 2017). In a recent study, 44.3% of surgical patients undergoing general anesthesia became hypothermic (Yi et al., 2017).

Sedation and premedication: Patients who were sedated and premedicated are at high risk of hypothermia under anesthesia (The Turkish Anaesthesiology and Reanimation Society Guidelines, 2013). Drugs used for preoperative anxiolysis can influence core temperature. Benzodiazepines, clonidine, and opioids can decrease the core temperature in a concentration-dependent matter (Rauch et al., 2021). Bräuer et al. (2019) found that oral premedication with benzodiazepines on the ward lowered core temperature significantly at arrival in the operating room.

Type of surgical procedure: The risk of hypothermia is higher in patients who will undergo major and moderate surgical interventions (The Turkish Anaesthesiology and Reanimation Society Guidelines, 2013). Compared to operations with less trauma such as laparoscopy, hypothermia is more common in major surgeries such as thoracic surgery, abdomen surgery due to the longer duration of the operation and greater blood loss during the operation (Aygin & Yaman, 2019; Liu & Qi, 2021; Sari et al., 2021). Multiple studies have shown a greater risk for hypothermia with abdominal procedures than other procedures (Akers et al., 2019). Also, in open surgical procedures, as the surgical incision area increases, the amount of heat lost from the body increases (Demirarslan, 2017).

Prolonged duration of anesthesia and surgery: Prolongation of anesthesia and

surgery (especially longer than one hour) increases the risk of hypothermia (Aldemir et al., 2021; Cho et al., 2021; Duman & Yilmaz, 2016; Emmert et al., 2018; Liu & Qi, 2021; Mendonca et al., 2021; Yan et al., 2021; Yi et al., 2017). The increased risk for hypothermia with a long operation time may be due to prolonged anesthesia time and increased blood loss and fluid demand, as well as increased heat loss by radiation and convection from the skin and by evaporation from within surgical incisions (Cho et al., 2021; Duman & Yilmaz, 2016).

Excessive loss of fluid or blood from the surgical site: Excessive blood and fluid loss during the operation causes an increase in heat loss (Aygin & Yaman, 2019; Liu & Qi, 2021).

Exposure of body surface: Exposure of body surface causes increased heat loss through radiation and convection and causes hypothermia during the surgical intervention (Bindu et al., 2017; Cho et al., 2021; Yuksel & Ugras, 2016).

Prolonged mechanical ventilation, excessive irrigation, and wet dressings are other factors that cause hypothermia during surgery (Cho et al., 2021; Yuksel & Ugras, 2016). Large intraoperative fluid application is an independent risk factor for the development of IPH (Emmert et al., 2018; Liu & Qi, 2021).

Postoperative risk factors

Hypothermia continues after the surgery since anesthetic drugs continue their effects on the central nervous system until removed from the body. At the same time, vomiting, bleeding, and shivering in the postoperative period, may change the heat balance and cause heat loss from the body and prolong hypothermia. The opening of the covers during the patient's admission to the clinic, the wet covers, the administration of cold IV fluids, blood and blood products, not wearing the clothes, not using active and/or passive warming methods cause postoperative hypothermia (Demirarslan, 2017; Yuksel & Ugras, 2016).

Adverse effects of inadvertent perioperative hypothermia

IPH causes various complications that increase morbidity and mortality in the perioperative process (Aygin & Yaman, 2019; Billeter et al., 2014). Even mild to moderate hypothermia augments the risk of serious perioperative complications (Mendonca et al., 2021). In a one-year retrospective study by Kim et al. (2019a), postoperative body temperature was found to be associated with mortality.

Cardiovascular system: Hypothermia is associated with postoperative cardiovascular events (Yan et al., 2021). Even in mild hypothermia, there is an increase in the release of catecholamines such as noradrenaline in the body due to the increase in the activation of the sympathetic system. This situation causes vasoconstriction in the vessels, resulting in deterioration of myocardial blood flow and an increase in the risk of cardiovascular complications such as high blood pressure, ventricular dysrhythmias, myocardial infarction, and cardiac morbidity (Aygin & Yaman, 2019; Yigit et al., 2012).

The respiratory system: As a result of the decrease in O_2 affinity of hemoglobin due to hypothermia, the amount of dissolved oxygen in the blood decreases, and sufficient oxygen cannot be left to the tissues. Anaerobic metabolism occurs due to tissue hypoxia and lactic acid accumulates. Metabolic acidosis and hyperventilation occur due to lactic acidosis. Hyperventilation triggers respiratory alkalosis and hypoxemia develops (Aygin & Yaman, 2019). The increase in the number of ventilations per minute due to hypothermia may cause acute lung injury, especially in those with lung disease (Yuksel & Ugras, 2017).

Hematological system: Hypothermia impairs coagulation and platelet function (Bindu et al., 2017; Rauch et al., 2021). Disruption of the coagulation mechanism leads to increased blood loss and transfusion requirements (Akers, et al., 2019; Aygin & Yaman, 2017; Yan et al., 2021). In a systemic review, it is reported that even mild hypothermia increases blood loss by an estimated 16%, and, mild hypothermia increases the risk for transfusion by approximately 22% (Rajagopalan et al., 2008).

Immune system: Hypothermia creates an immunosuppressive effect by causing deterioration in the function of the elements

involved in the immune system and increases the risk of infection such as surgical site infections (SSI) (Aygin & Yaman, 2019; Keskin 2021). The relationship between hypothermia and surgical site infection (SSI) is related to the type of surgical procedure (Oner Cengiz, Ucar & Yilmaz, 2021; WHO, 2016;). Patients who develop an SSI can experience a prolonged hospital stay, increased costs, and perioperative morbidity and mortality (Oner Cengiz et al., 2021; Rauch et al., 2021).

Endocrine system: Hypothermia causes an increase in cortisol, adrenaline, and noradrenaline levels (Keskin, 2021). Furthermore, the low use of glucose by the body, the decreased renal loss of glucose and insulin release, and increased peripheral insulin resistance may lead to increased blood glucose levels and hyperglycemia (Prado et al., 2015).

Excretory system: As blood is lost from the surgical area and vasodilation develops in skin vessels, glomerular filtration slows down as a result of decreased blood flow to the kidney. As the glomerular filtration slows down, the kidneys' ability to concentrate or dilute the urine and excrete drug metabolites and metabolic wastes slow down. Cold diuresis may develop due to hypothermia (Demirarslan, 2017).

Gastrointestinal system: Hypothermia causes ileus by slowing down intestinal functions and intestinal motility (Keskin, 2021; Yan et al., 2021), and increases the incidence of postoperative nausea and vomiting (Sahin Akboga, 2021; Keskin, 2021). Absence/slow bowel movements due to anesthesia cause distension that cause the surgical incision margins to move away from each other (Demirarslan, 2017).

Pharmacokinetic and pharmacodynamic effects: Hypothermia changes the bioavailability of many drugs and causes an increase in the activity and duration of action of narcotic and neuromuscular blockers (Demirarslan, 2017; Keskin, 2021; Yan et al., 2021). The decrease in renal circulation and hepatic function due to decreased tissue perfusion makes it difficult to excrete drugs from the body (Aygin & Yaman, 2019).

Impaired wound healing: Vasoconstriction due to hypothermia leads to deterioration in tissue perfusion and hypoxia, resulting in a delay in wound healing. Prolonged wound healing also increases the risk of surgical site infection (Inal et al., 2017; Keskin, 2021).

Pressure ulcer: Hypothermia is associated with increased pressure ulcer incidence (Fred et al., 2012; Gul, 2014). A study has shown that patients at higher risk for developing an intraoperatively acquired pressure ulcer are those who are critically ill, have a low Braden Scale skin assessment score, are thin, and are male with at least a 1.8°C drop in temperature (Fred et al., 2012).

Increased postoperative pain intensity: Hypothermic patients show significantly increased pain compared to normothermic patients (Mendonca et al., 2021). Therefore, perioperative warming of surgical patients is effective in reducing postoperative wound pain (Sajid et al., 2009).

Shivering: Postanesthetic shivering occurs in up to 40% of patients (Bindu et al., 2017). The etiology of postoperative shivering is not fully understood. However, it is stated that it may be due to physiological vasoconstriction, inflammatory response, and the release of cytokines against hypothermia (Duman & Yilmaz, 2016; Leeth et al., 2010; Park et al., 2012). The incidence of shivering is higher in younger patients and those with low core temperature. Shivering is associated with increased oxygen consumption, raised intraocular and intracranial pressures, surgical incision stretch causing wound pain, and morbid myocardial outcomes (Bindu et al., 2017).

Thermal discomfort: Hypothermia leads to deterioration in thermal comfort. Therefore, it is recommended to determine the temperature comfort by asking the patients whether they are cold before and after the surgery (Park & Choi, 2010; Rauch et al., 2021; Tunc-Tuna et al., 2022).

***Anxiety*:** Hypothermia causes increased anxiety about the surgical process in patients. Heating the patients in the perioperative process is effective in reducing anxiety (Kim et al., 2019b; Park & Choi, 2010; Tunc-Tuna et al., 2022). Hypothermia also causes more admission to postoperative intensive care

units and longer hospital stays compared to normothermic patients (Yan et al., 2021; Zhnag et al., 2021; Keskin, 2021). In a study conducted with patients undergoing general anesthesia, it was reported that patients with hypothermia are associated with more postoperative intensive care unit admission, delayed discharge from the postanesthesia care unit, and more postoperative hospital days compared to normothermic patients (Yieh et al., 2017). Emmert et al., (2018) reported that hospital length of stay was longer in patients with hypothermia after thoracic surgery. In addition to its negative effects on patient outcomes, hypothermia also leads to increased medical expenses (Keskin, 2021; Yan et al., 2021; Zhnag et al., 2021). Complications from hypothermia increase costs by $2,500 to $7,000 per patient (Russel et al., 2022). When hypothermia-based problems are considered, providing and maintaining normothermia in the perioperative period is important for optimal surgical results, patient safety, and satisfaction (Rauch et al., 2021).

Conclusion: IPH is a preventable surgical complication. However, despite the current technological and scientific developments regarding the prevention and management of IPH, it continues to be a problem. The factors that increase the risk of IPH in the surgical patient can be divided into patient-related and surgery-related risk factors. Determination of the incidence and risk factors of IPH may help to prevent IPH and its adverse effects in patients.

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