



Special article

Consensus of the Brazilian association of hematology, hemotherapy and cellular therapy on patient blood management

Inadvertent intraoperative hypothermia

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ABSTRACT

Hemostasis plays a critical role in surgical procedures and is essential for a successful outcome. Advances in hemostatic agents offer new approaches to controlling bleeding thereby making surgeries safer. The appropriate choice of these agents is crucial. Volume replacement, another integral part of Patient Blood Management (PBM), maintains adequate tissue perfusion, preventing cellular damage. Individualization in fluid administration is vital with the choice between crystalloids and colloids depending on each case. Colloids, unlike crystalloids, increase oncotic pressure, contributing to fluid retention in the intravascular space. Understanding these aspects is essential to ensure safe and effective surgery,

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Thermoregulation
Intraoperative management
Patient blood management

minimizing complications related to blood loss and maintaining the patient's hemodynamic status.

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Inadvertent intraoperative hypothermia

Inadvertent intraoperative hypothermia refers to a situation in which a patient's body temperature drops below normal during a surgical procedure. The pathophysiology of this phenomenon involves a combination of factors. The patient's exposure to a cold environment is a major contributor to intraoperative hypothermia. Operating rooms are typically kept at lower temperatures to reduce the risk of bacterial growth, but this can result in the patient's heat loss. Furthermore, the administration of anesthesia can lead to a decrease in the body's ability to regulate temperature, due to the action of the drugs on the regulatory center located next to the hypothalamus, thereby decreasing the afferent response to hypothermia.

Inadvertent preoperative hypothermia is one of the main adverse events in the course of care of hospitalized patients, whether in the operating room or in interventional procedure units. Publications report incidences above 20 % in the preoperative period, which reach beyond 60 % post-operatively.¹ The journey of this group of patients has currently been the subject of a structured Horizontal Care model, with strategies, protocols, general guidelines aiming at reducing the morbidity and making the patient's journey safe, positive and focused on preventing events, which are well known to the staff involved in preoperative care.

Preoperative hypothermia is defined as a core body temperature below 36 °C (96.8°F) at any time during the preoperative period. After induction of anesthesia, the most important cause of preoperative hypothermia is the distribution of body heat from the center to the periphery, an effect that contributes to much of the reduction in core temperature during the first hour of anesthesia (Figure 1).²

Thermoregulation

One of the main heat loss mechanisms involves radiation and convection during surgery, as patients are often unclothed to perform the surgery. They may also be subjected to procedures that involve internal organ manipulation which also contributes to heat loss. Furthermore, the use of cold intravenous fluids and air conditioning systems can contribute to hypothermia. The pathophysiology of inadvertent intraoperative hypothermia revolves around an imbalance between heat production and heat loss.

Heat production can be impaired by factors such as decreased metabolic rate during anesthesia, decreased muscle activity and the cooling effects of intravenous fluids. Heat loss, on the other hand, can occur by conduction (direct transfer of heat to a cooler surface), convection (transfer of heat to

the surrounding air) and evaporation (loss of heat through body surfaces - Figures 2 and 3).

The deleterious effects of hypothermia affect several body systems and structures, negatively impacting the surgical patient's outcome. Hypothermia itself can delay healing and predispose patients to wound infections. Maintaining normothermia intraoperatively will probably reduce the incidence of infectious complications in patients undergoing colorectal resection and shorten their hospitalizations.³

Hypothermia increases blood loss and the possibility of surgical site infections, in addition to prolonging postoperative recovery. Therefore, inadvertent non-therapeutic hypothermia is considered an adverse effect of general and regional anesthesia, which means that understanding hypothermia and its complications and the effective strategies for its prevention in the perioperative period are critical for healthcare providers. It is also essential to plan effective interventions that minimize or facilitate the prevention of complications resulting from anesthesia (Figure 4 and Table 1).²

The organization of a wide-ranging strategy aimed at prevention and active intervention in situations involving the surgical patient's journey must be a premise of good care dedicated to the patient. Communication within the surgical team is essential to understand and concern about how these events are essential for prevention. As examples, we can highlight information and communication with the patient and family, preoperative fasting time, occurrence of nausea and vomiting in the postoperative period, return to the patient's oral intake, guidance on stopping smoking in the preoperative period, reduction in intraoperative and postoperative use of opioids and inadvertent intraoperative hypothermia.

Strategies can be optimized with actions that seek to correct high prevalence events in this group of patients even in the preoperative period, including a reduction in the occurrence of inadvertent preoperative hypothermia. This can be achieved using a preoperative strategy such as heating using active heat transfer systems (e.g. thermal blankets, a technique that uses convection as a means of heat transfer) during hospitalization. Their maintenance in the intra- and postoperative periods helps to optimize care greatly reducing the occurrence of hypothermia, as well as giving clinical advantages (Table 2).⁴

Thirty-one patients were prewarmed in the inpatient unit using an active heated air system (Bair Hugger) for 60 min which continued with active warming intraoperatively and 37 patients in the control group were not. There was a smaller decrease of 0.3 °C in mean core temperature in the preheated group at 40, 60 and 80 min post-induction (p -value ≤ 0.05). The temperature was maintained above the hypothermic threshold of 36 °C in 21 (68 %) patients in the preheated group compared to 16 (43 %) patients in the control group (p -value < 0.05) (Figure 5).⁵

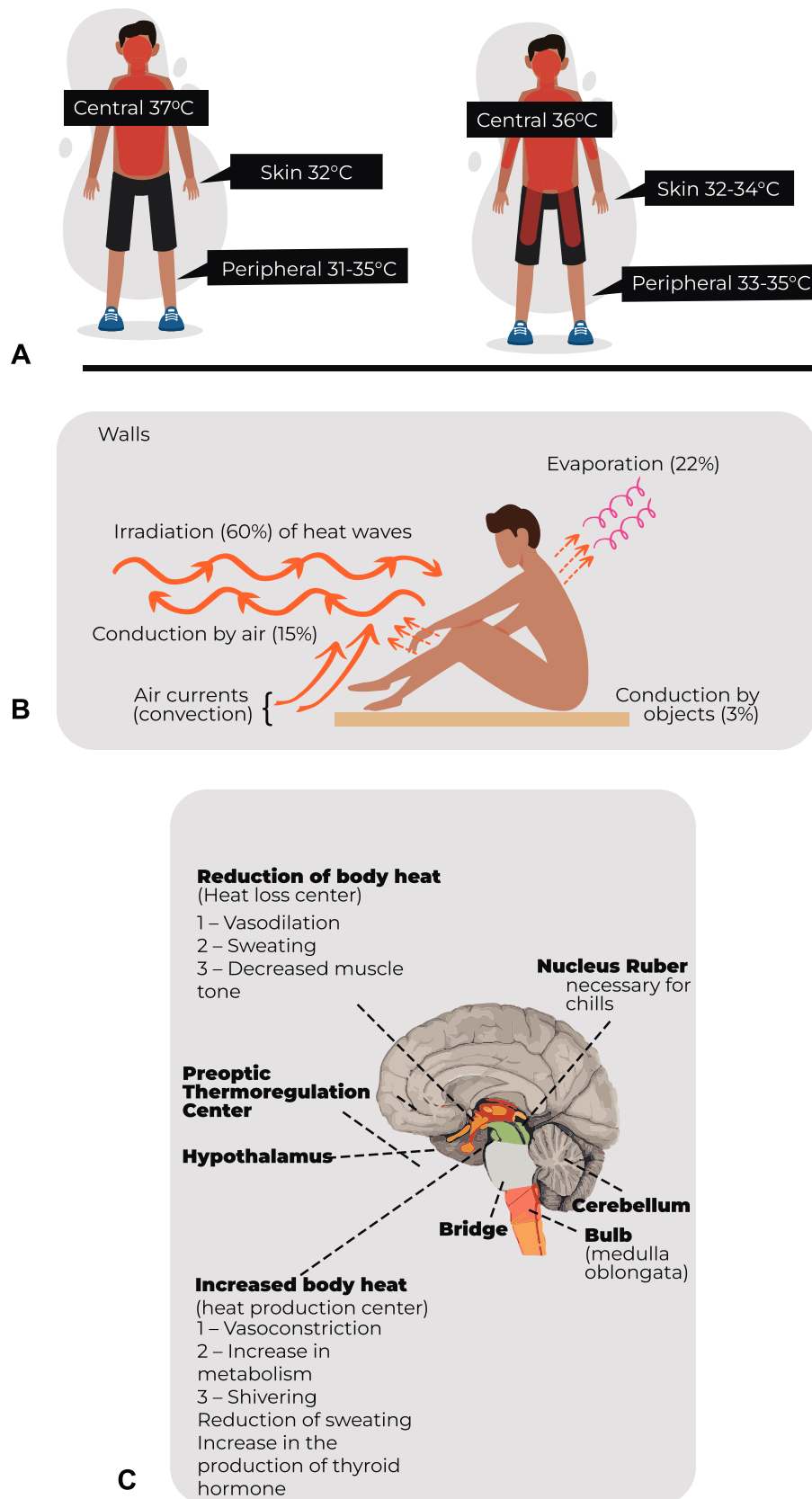


Figure 1 – Mechanisms of body heat distribution.

Adapted from Brazilian Guidelines for Preventing and Treating Inadvertent Perioperative Hyperthermia in Adults produced by the Sao Paulo State Society of Anesthesiology. J Infect Control 2018;7(1):01-16²

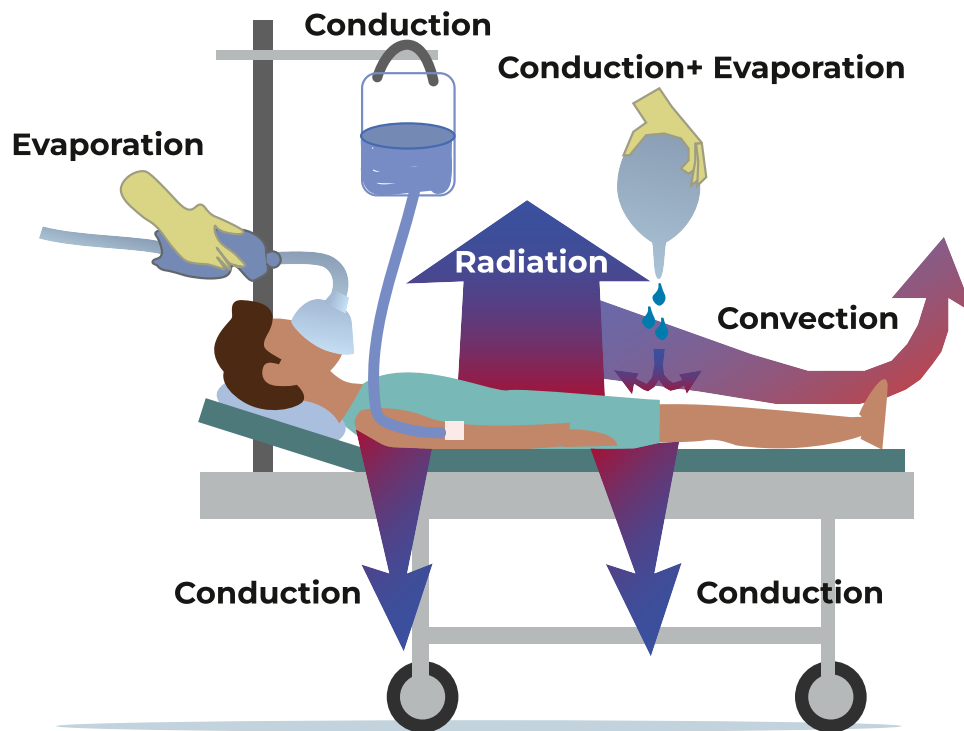


Figure 2 – Thermoregulation: perioperative mechanisms.

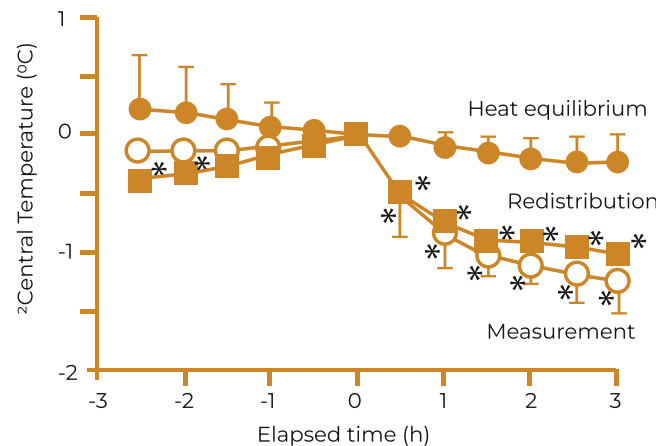


Figure 3 – Physiology of thermoregulation – hypothermia versus general anesthesia.

Patients should be well informed about the surgical procedure and discuss any concerns they have regarding hypothermia with their healthcare professionals.

Each case is unique and preventive measures may vary depending on the patient's characteristics and the type of surgery to be performed.

Furthermore, it was found that patients had a higher risk of cancer recurrence at one year if they had a low preoperative baseline body temperature ($<36.6^{\circ}\text{C}$ - 17 % vs. 10 %; $p\text{-value} = 0.034$). Low body temperature (mean body temperature $<37.4^{\circ}\text{C}$) after surgery was an independent predictor of poor survival outcomes in patients with rectal cancer.⁶

Body temperature is not homogeneous: in the surgical patient, deep thoracic, abdominal and central nervous system (i.e. core), temperatures generally vary by 2–4 $^{\circ}\text{C}$ in relation to

the arms and legs and much of the surface of the body, that is the skin, is even colder. Unlike the core temperature, which is tightly regulated, skin temperature varies markedly depending on environmental exposure (Table 3).

The temperature of peripheral tissues (mainly arms and legs) depends on present exposure, exposure history, core temperature and thermoregulatory vasomotricity. Core temperature, although it does not completely characterize the content and distribution of body heat, is the single best indicator of thermal status in humans. Core temperature monitoring (e.g., tympanic membrane, pulmonary artery, distal esophagus and nasopharynx) is used to monitor intraoperative hypothermia, prevent overheating and facilitate detection of malignant hyperthermia. Because these sites are not necessarily available or convenient, a variety of near-core

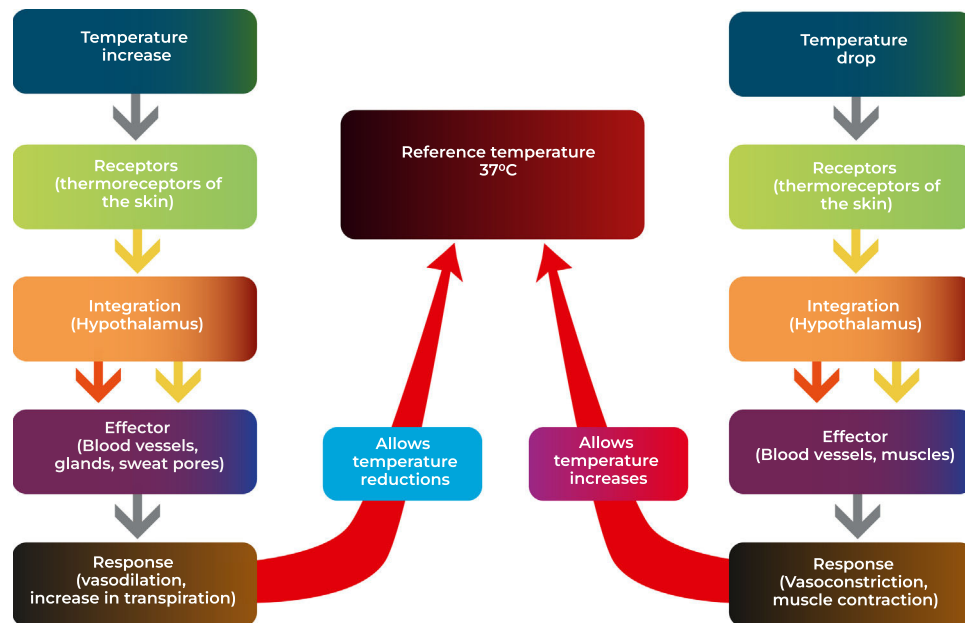


Figure 4– Hypothermia: interventions and associated complications.

Table 1 – Complications of hypothermia.

System	Complication
Cardiovascular	Myocardium ischemia Arterial hypertension Tachycardia
Coagulation	Deep venous thrombosis Platelet activation Coagulopathy
Immunology	Increased incidence of surgical site infections
Hydroelectrolytic	Hypokalemia Hypomagnesemia Hypophosphatemia
Endocrine-metabolic alterations	↓Corticoides ↓Insulin ↑Peripheral resistance to insulin ↑TSH → ↑thyroxin Hyperglycemia Hypoglycemia

Adapted from Brazilian Guidelines for Preventing and Treating Inadvertent Perioperative Hyperthermia in Adults produced by the Sao Paulo State Society of Anesthesiology. J Infect Control 2018;7(1):01-16.²

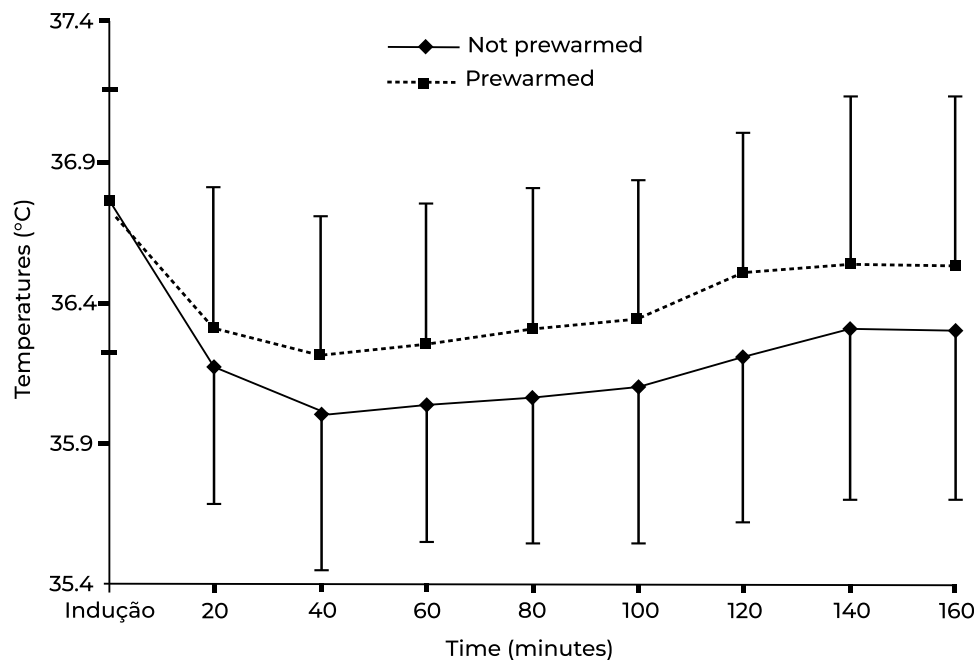
Table 2 – Consequences of mild perioperative and perianesthetic hypothermia in humans.

Consequence	Author	n	VT _{core} (°C)	Normothermic	Hypothermic	p-value
Morbid cardiac events		300	1.3	1.4 %	6.3 %	<0.05
Postoperative ventricular tachycardia	Frank et al.	300	1.3	2.4 %	7.9 %	<0.05
Adrenergic activation	Frank	74	1.5	330 ± 30	480 ± 70	<0.05
Cardiac wound infection	Kurtz et al.	200	1.9	pg/mL 6 %	pg/mL 9 %	<0.01
Hospital stay	Kurtz et al.	200	1.9	12.1 ± 4.4 days	14.7 ± 6.5 days	<0.01
Lymphocytic proliferation 24 hour after anesthesia	Beiln et al.	60	1.0	4800 CPM	2750 CPM	<0.05
Necessity of allogenic transplantation	Schmied et al.	60	1.6	1 unit	8 units	<0.05
Intraoperative blood loss	Schmied et al.	60	1.6	1.7 ± 0.3 L	2.2 ± 0.5 L	< 0.001
Intraoperative blood loss	Winkler et al.	150	0.4	480 mL	618 mL	<0.005
Intraoperative blood loss	Winkler et al.	46	0.5	516 ± 272 mL	702 ± 344 mL	<0.05
Intraoperative blood loss	Johansson et al.	50	0.8	665 ± 292 mL	698 ± 314 mL	NS

Table 2 (continued)

Consequence	Author	n	VT _{core} (°C)	Normothermic	Hypothermic	p-value
Urinary nitrogen excretion	Carli et al.	12	1.5	982 mmol/day	1798 mmol/day	<0.05
Trauma mortality in 24 h	Giantilello et al.	57	1.0–2.0	7 %	43 %	<0.05
Duration of vecuronium	Heier et al.	20	2.0	28 ± 4 min	62 ± 8 min	< 0.001
Duration of vecuronium	Caldwell et al.	12	2.0	0.20 min ⁻¹	0.15 min ⁻¹	<0.05
Duration of atracurium	Leslie et al.	6	3.0	44 ± 4 min	68 ± 7 min	<0.05
Postoperative shivering	Just et al.	14	2.3	141 ± 9 mL/min/m ²	269 ± 60 mL/min/m ²	< 0.001
Postanesthetic recovery duration	Lenhardt et al.	150	1.9	53 ± 36 min	94 ± 65 min	< 0.001
Thermal discomfort	Kurz et al.	74	2.6	50 ± 10 mm VAS	18 ± 9 mm VAS	< 0.001

Adapted from Reynolds L., Beckmann J., Kurz A. Perioperative complications of hypothermia. Best Pract Res Clin Anesthesiol. 2008 Dec;22(4). 645–57.⁴

**Figure 5 – Mean intraoperative temperatures (°C) used to calculate the area under the curve (AUC).****Table 3 – Risk factors for hypothermia.**

The following are risk factors for hypothermia

ASA grade greater than 1

Low preoperative temperature

Combined general and regional anesthesia

Major or medium surgery

Unheated intravenous, irrigation fluids and blood

Low environmental temperature

Irrigation fluids and blood were not used to detect cases of those at higher risk because the GDD recommends that all fluids and blood should be heated

Lower room temperature was also not used to detect cases of those at higher risk because the GDD recommends that the room temperature be at least 21 °C during patient preparation and that heating mechanisms be properly prepared for use.

Adapted from Brazilian Guidelines for Preventing and Treating Inadvertent Perioperative Hyperthermia in Adults produced by the Sao Paulo State Society of Anesthesiology. J Infect Control 2018;7(1):01–16.²

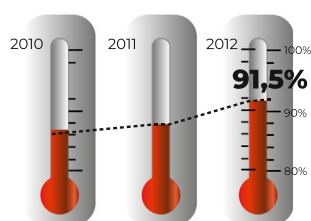
NICE Clinical-Practice-Guideline the management of inadvertent perioperative hypothermia in adults. National Collaborating Centre for Nursing and Supportive Care commissioned by the National Institute for Health and Clinical Excellence (NICE) <http://guidance.nice.org.uk/CG65>. 2014.⁷

Management of the intraoperative temperature is more than just to stay warm at the end of the surgery

In a national dataset from 2012, **69.6%** of eligible providers had a performance rate $\geq 90\%$...



and **91.5%** of anesthetists in 2012 met perioperative temperature measuring criteria...



but recent data suggests that intraoperative temperature may also be important, with an association found between intraoperative hypothermia and transfusion.

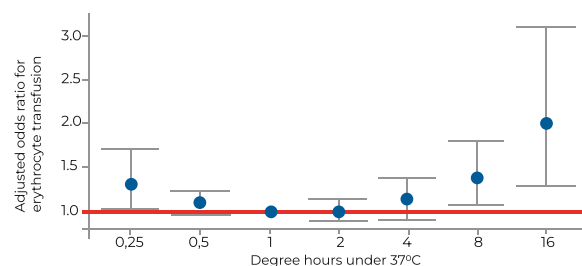


Figure 6 – Management of intraoperative temperature.

sites are also used clinically. These include the mouth, arm-pit, bladder, rectum and surface of the skin. Each has distinct limitations, but can be used clinically in appropriate circumstances. The level of precision that is clinically necessary has not yet been established. However, a good rule of thumb which has been used in many studies, is that the combined inaccuracy of a site/thermometer combination should not exceed 0.5 °C. One basis for this choice is that the smallest difference has proved to be associated with hypothermia-induced complications. Measuring tympanic temperature using a temperature sensor placed in the tympanic canal or close to the central nervous system (frontal region) allows for more precise and continuous measurements of core temperature (Figure 6).

incorrect anesthesia-induced temperature regulation, exposure of the patient's body and use of certain medical interventions. Understanding the pathophysiology of this condition is crucial to implementing effective preventative measures and optimizing patient outcomes.

Conflicts of interest

The authors declare no conflicts of interest.

REFERENCES

- Queiroz, G. Fatores de risco para hipotermia perioperatória. Afya. Available at: <https://pebmed.com.br/fatores-de-risco-para-hipotermia-perioperatoria>.
- Silva E, Fernandes F, Mendes F, Braz L, Fernandes G, Neto D, et al. Brazilian guidelines on interventions for preventing and treating inadvertent perioperative hypothermia in adults-produced by the São Paulo State Society of Anesthesiology. *J Infect Control*. 2018;7(1):01–16.
- Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of Wound Infection and Temperature Group. *N Engl J Med*. 1996;334(19):1209–15.
- Reynolds L, Beckmann J, Kurz A. Perioperative complications of hypothermia. *Best Pract Res Clin Anaesthesiol*. 2008;22(4):645–57.
- Andrzejowski J, Hoyle J, Eapen G, Turnbull D. Effect of pre-warming on post-induction core temperature and the incidence of inadvertent perioperative hypothermia in patients undergoing general anaesthesia. *Br J Anaesth*. 2008;101(5):627–31.
- Yu H, Luo Y, Peng H, Kang L, Huang M, Luo S, et al. The predicting value of postoperative body temperature on long-term survival in patients with rectal cancer. *Tumour Biol*. 2015;36(10):8055–63.
- NICE. Clinical-Practice-Guideline the Management of Inadvertent Perioperative Hypothermia in Adults. National Collaborating Centre for Nursing and Supportive Care commissioned by National Institute for Health and Clinical Excellence (NICE); 2014 <http://guidance.nice.org.uk/CG65>.

Recommendation

- Active prevention of intraoperative hypothermia is essential for adequate care of the surgical patient. This includes measures such as pre-warming using active heated air warming systems, such as the Bair Hugger, in the inpatient unit, as well as maintaining perioperative warming.
- Effective communication within the surgical team is essential to ensure that prevention of hypothermia is a priority at all stages of surgery. A shared understanding of the risks associated with hypothermia and prevention strategies is critical to ensure a coordinated and effective approach.
- Accurate monitoring of body temperature, preferably using core temperature measurement methods, such as the tympanic membrane, pulmonary artery, distal esophagus or nasopharynx, is crucial to detect and prevent hypothermia during surgery. This allows timely interventions to maintain the patient's body temperature within normal limits.

Conclusion

Inadvertent intraoperative hypothermia occurs due to a combination of factors such as a cold surgical environment,