REVIEW ARTICLE
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Refining Anesthesia Practice – Part 1: Temperature

ABSTRACT

Advances in surgery are often preceded by advancements in anesthesia. Bygone are the days when safety alone was the biggest anesthesia concern and goal. With the advent of safe anesthesia, the goal has gradually shifted toward maintaining patient physiology as close to normal as possible, while still ensuring a smooth surgical plane of anesthesia and patient safety. With this motive, we are starting the following series called "Refining Anesthesia Practice" to discuss and throw light on the finer aspects of anesthesia management. First, in this series, is the review article on temperature regulation under anesthesia.

Key words: Temperature regulation, Inter threshold range, Temperature monitoring, Hypothermia, Hyperthermia

Roshni Cheema, Pradnya Kulkarni

Department of Anesthesiology, BHIMS, Mumbai, Maharashtra, India.

Corresponding Author:
Dr. Roshni Cheema, Cheema Niketan, New R K Plots, Akola - 444001, Maharashtra, India. E-mail: roshniche28oct@gmail.com

INTRODUCTION

Body temperature is among the classical vital signs, and rightly so, since thermal perturbations both cause and indicate disease.[1] Mean core temperature in humans is 36.5–37.3°C. Tonic thermoregulatory vasoconstriction helps to maintain a temperature gradient between the periphery and the core, with the periphery being usually 2–4°C cooler than the core.[2]

Among perioperative thermal disturbances, inadvertent hypothermia is the most frequently encountered one. Evidence from randomized trials demonstrates that, even mild hypothermia can lead to significant complications such as surgical wound infections, platelet dysfunction, coagulopathy, increased allogeneic transfusions, and delayed postoperative recovery. As a result, ensuring normothermia during surgery has become a standard practice.[1]

Yet, body temperature is seldom monitored intraoperatively and treated even more rarely. This review article is first in the series of articles on refining and tailoring perioperative anesthesia management.

NORMAL THERMOREGULATION

The hypothalamus plays a crucial role in regulating body temperature, serving as the primary central structure responsible for this function. Through the integration of thermal input, the hypothalamus triggers effector mechanisms that adjust metabolic heat production and environmental heat loss to achieve temperature normalization. Less energy expensive responses such as vasoconstriction are maximally utilized before metabolically costly responses such as shivering are activated.

Physiology of thermoregulation in healthy humans

Afferent input

Cold signals carried by A delta and Warm signals carried by unmyelinated C-fibers reach hypothalamus through the spinothalamic tracts of anterior spinal cord.

Central regulation consists of effector responses which are primarily behavioral and autonomic reflex based. *Behavioral responses* consist of conscious decisions to avoid harsh temperatures such as moving away from sun to shade. *Autonomic response* is made up of efferent response arm which consists of:

- Cutaneous vasoconstriction
- Non-shivering thermogenesis (can double heat production in infants)
- Shivering (last response to cold, increases metabolic heat production by 50–100% in adults)
- Vasodilation (response to heat)
- Sweating (active process mediated by postganglionic cholinergic nerves. Nerve blockade and atropine prevent it. Reduces body temperature.

Interthreshold range

The interthreshold range refers to the range of temperatures, in which autonomic responses are not triggered. This range is defined by the lower vasoconstriction threshold at one end and the upper sweating threshold at the other end. Vasoconstriction and shivering are activated at 36.5°C and 36°C, respectively. General anesthesia lowers this threshold by 2–3°C.[2] This is significant because it implies that post anesthesia shivering is indicative of a lower core temperature than shivering in a normal non-anesthetized human.

FROM HOMEOTHERMS TO POIKILOTHERMS UNDER ANESTHESIA

Behavioral responses to temperature fluctuations are abolished in an anesthetized person and anesthesia causes significant depression in autonomic regulation turning an otherwise homeothermic human into a poikilotherm that changes body temperature with changing environmental temperature.

Causes of loss of temperature regulation under anesthesia

Operational technology (OT) environment

During surgery, the OT environment is carefully controlled to maintain specific temperature and humidity levels and to prepare the body surface and equipment for the procedure. However, the use of cold intravenous fluids, such as red blood cell transfusions, can lead to a drop in body temperature of approximately 0.25–0.35°C/unit administered.

Surgical technique

Exposure of body cavity and duration of surgery.

Anesthesia

Anesthesia has several effects on thermoregulation in the body. It leads to a redistribution of heat from the core to the periphery and can also reduce the metabolic rate by 20–30% during general anesthesia. However, dry anesthetic gases and volatiles can impair thermoregulatory vasoconstriction, whereas muscle relaxants can prevent shivering. Intravenous sedatives and induction agents, such as Propofol, sufentanil, dexmedetomidine, and clonidine, increase the sweating threshold and significantly lower the shivering threshold. In regional anesthesia, hypothalamic reflexes are intact. Efferent signals below level of block impaired. Heat loss is enhanced by vasodilation.

TEMPERATURE MONITORING

Since patients under anesthesia behave such as poikilotherms, the onus of temperature monitoring and management lies solely on the anesthesiologist. It is widely agreed upon that monitoring of core temperature is necessary when general anesthesia exceeds 30 min, as well as during neuraxial anesthesia of similar duration. However, sedation and peripheral nerve blocks typically have only minor effects on thermoregulatory control and rarely result in significant hypothermia.[1]

Sites of temperature monitoring

Core

Pulmonary artery, distal esophagus, tympanic membrane, nasopharynx can be measured using disposable temperature probes [Figure 1]. These are reliable even during extreme thermal perturbations.

Intermediate sites

Oral cavity, rectum, and bladder. Not reliable during rapid thermal variations.

Skin surface

Considerably lower than core temperature.

INADVERTENT INTRAOPERATIVE HYPOTHERMIA

The most frequent thermal complication during the perioperative period is inadvertent intraoperative hypothermia, which is characterized by a core temperature below 36°C. The incidence of this condition ranges widely, from 6% to 90%.[3,4] Post-anesthetic shivering occurs in up to 40% of patients.[2,5,6] This can lead to a range of negative outcomes, including increased oxygen consumption by as much as 100%, raised intraocular and intracranial pressures, stretching of surgical incisions resulting in wound pain, and adverse myocardial events. Compared to vasoconstriction threshold, meperidine has a greater effect in reducing the shivering threshold. In addition, dexmedetomidine is a newer agent that can reduce both vasoconstriction and shivering thresholds, making it a highly effective treatment for shivering.

WHY IS THE PATIENT UNDER ANESTHESIA LOSING HEAT?

Phase 1

Redistribution – 0.5–1.5°C fall in core temperature in the first hour itself due to anesthetic-induced vasodilation causing redistribution of heat from core to periphery. It depends on core to periphery temperature gradient and accounts for 81% temperature fall. This is very important because it implies that prewarming the patient for even as less as 30 min reduces this gradient and heat loss due to redistribution after vasodilation.

Phase 2

Linear heat loss, lasts for the next 2–4 h, occurs because heat loss exceeds metabolic heat production And depends on the size of patient and area exposed.

Phase 3

Plateau phase occurs after 3–4 h. Core temperature stabilizes due to vasoconstriction and core metabolic heat trapping.

However, peripheral temperature and total body heat continue to be lost, hence not a thermal steady state.

Most of our current attempts focus on intraoperative temperature monitoring and management. However, understanding the above physiology gives us the rationale to consider prewarming as an easier and more productive way of heat conservation under anesthesia. By implementing a combination of prewarming and intraoperative warming in the anesthesia induction room just before the start of surgical procedures, hypothermia rates of 15.8% during surgery, and 5.1% in the postoperative period can be achieved in clinical practice.[7]

HEAT LOSS UNDER NEURAXIAL ANESTHESIA

Neuraxial anesthesia, like general anesthesia, has a negative impact on both behavioral and autonomic thermoregulation. This type of anesthesia blocks all thermal input from anesthetized areas and reduces vasoconstriction and shivering thresholds by 0.6°C above the level of the block. The severity of hypothermia during neuraxial anesthesia is similar to that experienced during general anesthesia, with core temperature decreasing by 0.5–1.0°C.[8] Unlike general anesthesia, nerve block inhibits peripheral vasoconstriction, which can cause the decrease in core temperature to continue without leveling off. As a result, patients under regional anesthesia may not be aware that they are hypothermic, and their cold defenses may be difficult to activate and less effective.[2,9]

MEASURES TO PREVENT INTRAOPERATIVE HYPOTHERMIA

- Preoperative warming
- Airway heating and humidification
- Warming intravenous fluids
- Cutaneous warming – Different types of active warming devices are available for maintaining normothermia during surgeries. These include circulating-water mattresses and garments, forced-air warming systems [Figure 2], resistive heating devices, negative pressure water warming systems, and radiant heaters. Underbody warming devices or mattresses are preferred in surgeries where the use of blankets is not feasible. However, they may not be superior to over-the-body warming devices because they can reduce perfusion to dependent areas. Warming mattresses have also been found to effectively maintain temperature during the pre-bypass period in cardiac surgeries.[10]
- Postoperative warming therapy – passive warming methods have low efficiency and may take a long time to raise the patient's temperature due to sustained peripheral vasoconstriction. Thus, intraoperative warming is considered the optimal approach. Furthermore, active warming is more effective than passive warming alone for postoperative warming, as it helps patients recover their normal body temperature 1 h earlier.[2]

Figure 1: Disposable temperature probe

Figure 2: Bair-body hugger warmer with warming blanket

HYPERTHERMIA UNDER ANESTHESIA

Hyperthermia is more dangerous than a similar degree of hypothermia. It leads to discomfort and increased metabolic demand and cardiovascular stress. Inadequate monitoring of core temperature during excessive heating of a patient can lead to passive hyperthermia, which is often observed in infants and children due to their less effective sweating response under anesthesia.[11] Infants regulate their temperature remarkably well, but it is less robust in neonates and elderly.

CONCLUSION

Temperature continues to be vital yet least monitored and managed parameter under anesthesia. Preoperative warming for as less as 25 min was shown to effectively reduce intraoperative inadvertent hypothermia, need of post anesthesia warming and shivering. General anesthesia and neuraxial blockade both cause similar degree of hypothermia. Any surgery lasting over 30 min advocates use of core temperature monitoring. To conclude, The aim of anesthesia is to maintain patient physiology as close to normal as possible. Doing so is only possible if we as perioperative physicians give meticulous attention to the need of perioperative temperature management.

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