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HYPOTHERMIA IN NEUROSURGICAL PATIENTS: RISK AND BENEFITS

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Detection of abnormal body temperature facilitates proper diagnosis and evaluation of presenting complaints. The inability of any patient to maintain normal body temperature is indicative of a vast number of potentially serious disorders, including infections, neoplasms, shock, toxic reactions, and environmental exposures. Neurosurgical patients are especially vulnerable to temperature changes. More frequently, intraoperative thermal dysregulation results in hypothermia. Our chapter relates different etiology, pathophysiology and clinical strategy of intraoperative hypothermia in neurosurgical patients.

Key words: intraoperative hypothermia, neurosurgical patients

Physiology and pathophysiology of thermoregulation.

Body temperature is normally regulated between 35.8 and 37.2°C (96.5 and 99°F). This tight control of body temperature is achieved by the hypothalamic autoregulatory center, which has an extremely high feedback gain for a biologic system [1, 2]. Processing of thermoregulatory information occurs in three phases:

- **Afferent input:** Temperature sensitive cells fire in response to excessive cold and heat. Information is transmitted in distinct neural fibers via multiple spinal tracts to the hypothalamus where it is then processed.
- **Central control:** Most of the processing takes place in the hypothalamus, where input from different sites is compared and integrated, and responses are regulated when deviation from threshold appears. Many factors influence the absolute threshold and normal core temperatures in humans. Distinguishing normal deviations from pathological states is of major importance. Drugs are related to or causing hypothermia: alcohol, phenothiazines, narcotics (morphine), anesthetic agents (isoflurane), sedatives, tricyclic antidepressants, barbiturates, hypnotics, lithium, hypoglycemic agents, antithyroid medications, paralytic agents, prazosin, heroin, cannabis, ethylene glycol, organophosphates. The inter-threshold range is a range bounded by sweating on the upper end and shivering on the lower end where perturbations of 0.2°C from threshold do not typically trigger an autonomic response.
- **Efferent response:** Thermal perturbations from normal limits activate effector responses that increase metabolic heat production or alter environmental heat loss. Each thermoregulatory effector has its own threshold and gain, so there is an orderly progression of responses and response intensities in proportion to need. Aside from autonomic responses, behavioral responses play an important role, and the lack of this response

in anesthetized patients should be taken into account.

More frequently, intraoperative thermal dysregulation results in hypothermia

Thermoregulation during anesthesia

Thermoregulation during anesthesia – general or regional – is often significantly impaired [3, 4]. Anesthetics may modulate thermoregulatory thresholds and influence effector responses. Other factors prevalent in the operating room (OR) environment and in surgical procedures, such as cold surroundings, exposed body surface, cold IV fluid replacement, and mechanical ventilation further contribute to the difficulty in maintaining normothermia. Incidence of perioperative hypothermia is reported to be as high as 70% and is of major concern particularly in lengthy procedures. Hyperthermia is a less frequent intraoperative complication, but when occurring – may have devastating effects in the context of central nervous system injury. Later in this section mild hypothermia will be discussed as a controversial treatment modality in neurosurgery. (Table) [5].

Table

Summary of thermoregulatory alterations during general anesthesia

Influences of Anesthesia on thermoregulation	
Behavioral responses	Abolished
Thermoregulatory threshold	Significantly altered. Reduced from 37°C to 34.5°C, interthreshold range widened to ± 4°C, sweating threshold slightly elevated, and vasoconstriction threshold markedly lowered.
Vasoconstriction	Impairment of vasoconstriction response, primarily in AV shunts, affects redistribution of body heat.
Shivering thermogenesis	Impaired by all general anesthetics, even without muscle blockade.

Non-shivering thermogenesis	Primarily affects infants who depend on this mechanism. In adults – an insignificant mechanism.
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Prevention – Hypothermia

Body heat redistribution following anesthesia follows a specific pattern, extensively studied by Sessler et al. The physician's role is crucial in intervening in each of these phases, minimizing the development and extent of hypothermia.

Phase 1: Redistribution hypothermia, once initiated, is extremely difficult to treat, since it is a result of heat flow from core to periphery (rather than cutaneous heat loss) and warming the core compartments is a lengthy procedure. Nevertheless, this phenomenon may be prevented by following means:

- Increasing body heat content by prewarming the patient 1 hour preoperatively.
- Pharmacologic vasodilation preoperatively, inducing redistribution prior to anesthesia.
- Phenylephrine induced vasoconstriction during the first hour of anesthesia has been shown to decrease the extent of redistribution hypothermia.

Phase 2: Most of the heat lost during this stage is due to radiation or convection. Thus, effectively interrupting these pathways has been found to be effective in minimizing heat loss. Approximately 90% of body heat is lost via the skin surface. Another 10% is lost via surgical incisions and cold IV fluid administration. Another negligible amount of heat is lost through respiration. In neurosurgical cases involving large incisions or massive fluid shifts, heating IV fluids has a greater significance. Cutaneous insulation and warming remains the mainstay of preventing perioperative hypothermia and include the following:

- Raising ambient temperature: This minimizes heat lost to radiation. Often, controlling ambient temperature may be impractical, as the ambient temperature necessary may reach levels too high to be tolerated by the scrubbed-in surgical team (e.g. 23°C-26°C for an infant patient).
- Cutaneous warming: Passive insulation is highly effective. A single layer of cotton blankets or surgical drapes reduces heat loss by as much as 30%, while the effectiveness of subsequent layers decreases. Heat preservation is proportional to the body surface area insulated. This is important with respect to infants whose proportions are different from those of adults (i.e. covering the head may be of significance.).
- Active warming: Two main methods – forced warm air and circulating heated water – are clinically used for active warming. Since 90% of heat loss is via skin surface, cutaneous heating is an efficient way of elevating core body temperature. Thermoregulatory vasoconstriction impairs heat flow from the periphery to core and poses a difficulty in warming unanesthetized hypothermic

patients efficiently. Therefore, active warming is best when applied to vasodilated anesthetized patients. Numerous studies have shown use of forced warm air to be superior to circulating hot water systems, albeit some studies demonstrate quicker heating with circulating water systems. When used, circulating hot water systems should be applied on top of the patient rather than underneath, as most foam mattresses provide good insulation and patient weight impairs cutaneous blood flow and increases risk of burns.

- Heated IV fluids: Heated IV fluids (limited to 40°C) are not sufficient to maintain normothermia in anesthetized patients. Nevertheless, in cases involving large fluid shifts, extensive blood loss or extremely long procedures, heated IV fluids provide some protection against development of hypothermia associated with cool IV fluid administration.
- Warmed and humidified gasses: As this route of heat loss is negligible in adults, there is no significant benefit of warming inspired gasses. Infants might have some benefit, as this route is somewhat more significant for them.

Crisis Management – Hypothermia

Managing hypothermia, once initiated in the intraoperative period, includes temperature monitoring and adequate warming. Complications of hypothermia should be sought and treated as indicated [7].

Monitoring Sites:

Five monitoring sites reliably provide core temperature – pulmonary artery (which is the gold standard), distal esophagus, nasopharynx, tympanic membrane, and bladder. Other sites may be both inaccurate and misleading, recording temperatures other than core temperature.

Complications of perioperative hypothermia:

Perianesthetic hypothermia produces potentially severe complications. The controversial benefits of mild hypothermia in the neurosurgical setting will be discussed further below.

Wound infection and healing:

Wound infection and impairment of healing are among the most common serious complications of anesthesia and surgery, known to increase morbidity and lengthen hospital stay.

Coagulation:

Coagulation is impaired in hypothermic patients and is thought to be mainly a result of a decrease in activity of clot activating factors. Other mechanisms shown to be impaired include platelet function and the fibrinolytic system. Two points should be kept in mind:

- Platelet count is not affected;
- Routine coagulation studies will usually result in normal coagulation function, as these tests are performed routinely in an environment of 37°C.

Adverse myocardial events:

Mild hypothermia has been shown to increase the risk three-fold of postoperative adverse myocardial events. Particular care should be taken with patients suffering from preexisting cardiac ischemic disease, and elderly patients.

Drug metabolism:

Drug metabolism is decreased by perioperative hypothermia, and postanesthetic recovery is prolonged.

Postoperative shivering:

Patients report shivering and thermal discomfort as their worst experience of the perioperative period, even worse than surgical pain. Of particular interest in neurosurgery – shivering increases ICP and intraocular pressure, in addition to stretching surgical incisions, and interrupting monitoring devices. Incidence is as high as 40%, but decreases when patients are kept normothermic and larger doses of opioids are used intraoperatively. Shivering may increase metabolic rate and oxygen consumption by 200%. The approach to postoperative shivering should include:

- Skin surface warming: Shivering threshold is dependent on core and mean skin temperature. Thus, aside from heating, this augments cutaneous warm input, allowing more core hypothermia, decreasing the shivering threshold. Skin warmers increase mean skin temperature by only a few degrees, thus it is important to raise core temperature > 35°C, for augmentation of warm input to be efficient and to prevent shivering.
- Drugs: Meperidine (25-75 mg IV) is considerably more effective in treating shivering than equianalgesic doses of other μ -agonists, and this may be attributed to its effect on k receptors. Clonidine (75-150 μ g IV, most probably by reducing vasoconstriction and shivering thresholds), Ketanserin (10 mg IV), Tramadol (1-2 mg/kg), Physostigmine (0.04 mg/kg), Magnesium Sulfate (30 mg/kg).

Therapeutic hypothermia in neurosurgery:

The decrease in metabolic rate and oxygen demand has led researchers and clinicians to postulate that hypothermia might have beneficial effects on neurological outcomes, in a vast array of situations involving cerebral ischemia and brain trauma [8, 9]. While numerous studies have shown mild hypothermia to provide protection against cerebral ischemia and hypoxemia in animal species, the only benefit unequivocally proven in humans is on the neurological outcomes following cardiac arrest / ventricular fibrillation.

Global Ischemia:

Several studies have shown improved neurological outcome and reduced mortality in comatose survivors after cardiac arrest treated with mild hypothermia (32°C-34°C) for a period of 12 – 72 hours.

Intracranial aneurysms:

Human controlled studies have not shown clear-cut beneficial effects of hypothermia. A number of studies show some possible benefit of hypothermia as a last resort treatment for carefully selected subgroups of patients suffering cerebrovascular spasm (CVS) following subarachnoid hemorrhage (SAH). Nevertheless – complications are often severe and should be closely monitored.

Traumatic brain injury:

Hypothermia as a protective mechanism in traumatic brain injury is under debate. It has been shown to decrease ICP. Some studies have been able to show some benefit in particular subgroups of the study. Recent investigations show no overall beneficial effect of hypothermia on outcomes of traumatic brain injury. When a decision to induce hypothermia does occur – several factors must be taken into consideration:

- Opposing thermoregulatory responses to hypothermia: This means providing anesthesia /sedation and preventing shivering.
- Cooling techniques: There is wide variety of techniques, invasive and non-invasive. The most appropriate technique should be selected.
- Rewarming: There is no consensus on the ideal time or rate for rewarming patients. Common practice is 0.5°C-1°C / hour. When hypothermia is prolonged, rewarming may be as gradual as 1°C/day.

Conclusion

General anesthesia impairs normal regulation significantly. Effector mechanisms preventing hypothermia include: Vasoconstriction, Shivering, and Non-shivering thermogenesis. Factors contributing to hypothermia which may be modified include: OR ambient temperature, drugs, exposure and duration. Core body temperature monitoring is extremely important. Intervention in three phases of hypothermia is crucial: Phase 1 – minimizing redistribution hypothermia. Phase 2 – minimizing heat loss due to radiation or convection. Phase 3 – monitoring and prevention of hyperthermia in the vasoconstriction phase. Perioperative hypothermia causes a variety of systemic complications and should be avoided.

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ТҰЖЫРЫМ

Атипті дене қызуын анықтау науқасқа диагноз қоюды жеңілдетіп, күрделі мәселелерді анықтайды. Науқастың дене қызуын қалыпты деңгейде ұстай алмауы көптеген қауіпті сырқаттардың кең спектрлі көрінісі болып табылады. Олар: инфекциялар, қатерлі ісіктер, шок, улы әсерлер және қоршаған ортаның әсері болуы мүмкін. Нейрохирургиялық науқастар дене қызуына өте сезімтал болып

келеді. Операция кезіндегі терморегуляцияның өте жиі бұзылуы гипотермияға әкеледі. Осы мақалада біз нейрохирургиялық науқастарда кездесетін гипотермияның даму этиологиясы, патофизиологиясы, клиникалық көрінісімен емдеу стратегияларын көрсетіп отырмыз.

Негізгі сөздер: нейрохирургиялық науқастар, гипотермия.

РЕЗЮМЕ

Выявление абнормальной температуры тела облегчает постановку правильного диагноза и выявление серьезных проблем. Неспособность пациента поддерживать адекватную температуру тела является проявлением широкого спектра потенциально серьезных болезней, включая инфекции, новообразования, шок, токсические реакции и влияние окружающей среды. Нейрохирургические пациенты являются особенно

чувствительными к изменениям температуры. Наиболее часто интраоперативные нарушения терморегуляции приводят к гипотермии. В данном обзоре мы описываем этиологию, патофизиологию, клинические проявления и лечебные стратегии при развитии гипотермии у нейрохирургических пациентов.

Ключевые слова: нейрохирургические пациенты, гипотермия.