SPECIAL ARTICLE

Perioperative hypothermia in pediatric patients: diagnosis, prevention and management

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ABSTRACT

Hpothermia is the most common perioperative disturbance in pediatric patients. Pediatric patients are highly vulnerable to hypothermia and its associated complications, e.g. respiratory embarrassment, metabolic acidosis, hypoglycemia, hypoxemia, cardiac disturbances, coagulopathy, and a higher incidence of wound infection etc. This higher vulnerability is mainly due to increased heat loss from larger head size, thin skin, lack of subcutaneous pad of fat and limited ability of compensatory thermogenesis from brown fat. As such it is mandatory to design appropriate diagnostic, preventive and therapeutic strategies which can effectively protect pediatric population from the potential catastrophic complications associated with hypothermia during perioperative period. The current review aims to refresh the basic mechanism of hypothermia and discussion of evidence based management strategies to minimize the incidence of hypothermia in pediatric patients.

Key words: Perioperative, Hypothermia, Thermoregulation, Thermogenesis

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INTRODUCTION

Inadvertent hypothermia, defined as a core temperature below 36˚C, is the most common form of perioperative disturbance in pediatric population. The incidence of hypothermia can be up to 20% among patients undergoing major surgical procedures. Perioperative hypothermia is associated with several complications, which can adversely affect the patient outcome, especially in high risk patients.[1] A combination of proportionately higher heat loss, a diminished ability to produce endogenous heat and a diminished thermoregulatory response makes infants highly vulnerable to developing hypothermia.[2] Although, not as well described in literature as in adults, perioperative hypothermia has been associated with a number of serious complications in infants.[3] The current review aims to discuss the importance of maintaining normothermia in pediatric patients, predisposing risk factors for inadvertent perioperative hypothermia and methods to detect and prevent perioperative hypothermia in children.

Thermoregulatory Mechanism during Anesthesia

Normal thermoregulation in infants in response to hypothermia is primarily augmented by vasoconstrictor response and nonshivering thermogenesis. Vasoconstrictor response is characterized by shunt vasoconstriction as an initial response to cold exposure. The thermoregulatory threshold is decreased by general anesthetic agents. While volatile anesthetics cause inhibition nonlinearly, higher concentrations being more effective; propofol and opioids cause a linear inhibition.[4-7]

The most effective thermoregulatory response in infants is nonshivering or brown fat thermogenesis. Brown fat is located at nape of the neck, interscapular region, axillae, and groin and around the kidneys and adrenals. Oxidation of triglycerides releases fatty acids to be consumed in generation of heat which is distributed through the blood stream to various parts of the body. Clinically significant nonshivering thermogenesis is thought to be present up to 2 years of age. It might, however, be inhibited by anesthetics agents and this fact may play a critical role in development of intraoperative hypothermia.[8-10]

Minimal development of musculoskeletal mass makes shivering an insignificant mechanism of thermogenesis in infants. The shivering response probably does not become important until early childhood, although age dependence has never been firmly established.[11] Protective mechanisms from hypothermia and shivering mechanism even in the higher age group to some extent are influenced by pharmacogenomics and pharmacogenetic factors.[12]

Perioperative period is the time when child is exposed to a cold environment of operating room (OR) due to administration of non-warmed intravenous fluids, and potential evaporation from the operated areas. However, these factors alone usually do not cause hypothermia as such. Caution has to be exercised even during the recovery phase and in postoperative wards which mandates the need for postoperative rounds by the anesthesiologists.[13] Although thermoregulatory vasoconstrictive mechanism is efficient in infants and children, they are functionally similar to adults in being unable to increase the metabolic rate in response to even mild hypothermia under anesthesia. In fact, it is the failure of effective thermoregulatory defenses which induces hypothermia in a child.

Induction of general anesthesia results in a three-phase decrease in core temperature; core-to-peripheral heat redistribution, linear core temperature decline, and core temperature plateau.[14] Initially, vasodilatation caused by anesthetic agents results in redistribution of heat from the core to the periphery. Body heat content remains unchanged. Infants and children experience little heat redistribution because of their small extremities with respect to torso. As a result, redistribution may have a less contribution to intraoperative hypothermia.[15]

The initial phase of redistribution is followed by a stage of thermal imbalance in which there is net heat loss to environment. The heat is lost mainly by radiation, convection, conduction and evaporation. Radiation is responsible for maximum heat loss up to an extent of 40% and is proportional to environment / core temperature difference. Convection is the other major source of heat loss and denotes the loss of heat to air molecules surrounding the body. Conductive heat loss is due to difference in temperature between body and surfaces in contact. Evaporation refers to heat loss from skin, respiratory, bowel and wound surfaces. The pediatric patients are vulnerable to intraoperative hypothermia because of increased heat loss due to their large surface area to weight ratio, large head with thin scalp and skull, thin skin which increases evaporative losses and lack of subcutaneous fat.[16]

After three to four hours during intra-operative period, core temperature reaches a plateau reflecting a state in which heat loss is equal to heat production. Usually the core temperature plateau occurs at a lower temperature,[17] although the core temperature is maintained during this phase. This may mask a continuing decrease in body heat content as the loss from extremities continues unabated.

There have been few studies identifying specific risk factors for intraoperative hypothermia in pediatric age group. Tander et al, evaluated the factors responsible for predisposing to intraoperative hypothermia in sixty neonates and infants.[18] The study concluded that infants had less decrease in temperature than neonates during both major and minor surgery and that the operating room temperature below 23˚C could significantly interfere with the maintenance of the neonate and infant's core temperature during anesthesia.[18] A study in children under 18 years of age by Pearce B et al, revealed that hypothermia was significantly associated with preoperative lower baseline temperature and the type of surgery (major or minor).[19]

CONSEQUENCES OF HYPOTHERMIA

If the ongoing hypothermia is not taken care of, many complications can occur in neonates, infants and children. Respiratory embarrassment[3] or apnea[2] can be dangerous complications. Both non-shivering and shivering thermogenesis increase oxygen consumption leading to hypoxemia and carbon dioxide retention, metabolic acidosis, hypoglycemia and a shift of oxygen dissociation curve to the left with resultant decreased oxygen delivery to the tissues.[20] Adult studies have shown that hypothermia may cause cardiac problems, impaired platelet function and clotting factor enzyme function, thus increasing the requirement of allogenic blood transfusion. It also facilitates wound infections. Moreover, there can be altered metabolism of drugs,[21] thermal discomfort,[22] an impact on the patient outcome and resultant increased costs.[23]

MONITORING OF TEMPERATURE

Continuous temperature monitoring in children receiving general anesthesia is recommended as per the guidelines laid down by American Society of Anaesthesiologists (ASA). Any site which appropriately measures core body temperature can be chosen for such diagnostic intervention. The choice of method used to measure temperature is based on the level of invasiveness and the degree of accuracy.[24] There are a variety of sites, each with its specific merits and demerits which can be summarized as Table 1.

PREVENTION

Prevention is better than cure. This proverb has probably not been more true in any other situation than in prevention of hypothermia in infants and children.

1. ***Parents/caregivers education*** to keep the child warm during preoperative hospital stay as well as during the transfer to the operating room so as to avoid the risk of hypothermia and its complications. The biopsychosocial perspectives related to various anesthetic techniques and drugs have to be explained to the parents for their complete.[26]
2. ***Preoperative assessment*** *should be thorough and*

Table 1: Probable sites for temperature monitoring

Site/Methodology	Clinical Significance
Pulmonary Artery Catheter	measures core temperature most accurately However it is reserved for patients requiring intensive hemodynamic monitoring due to its invasiveness and cost of the catheters
Distal Esophageal	Measures accurately core temperature but may be affected by humidified gases and in surgeries where chest cavity is opened like during open heart or lung surgery
Nasopharyngeal	May be affected by inspired gases
Bladder	Efficiency may be affected with low urine output, lower abdomen procedures
Tympanic	Non invasive measure of core temperature Patency of external auditory meatus is a must
Rectal	Accurately reflects the core temperature but results might be effected by stools and bacteria that generate heat
Axillary	For accurate measurement probe should be positioned over the axillary artery and the arm to be kept at the patient's side
Skin temperature measured over the carotid artery	Using a simple correction factor of +0.52°C,this is an accurate noninvasive measure of nasopharyngeal temperature Avoid risk of nose bleeding ,infection [25]

should specifically aim at:

- preoperative checking of the temperature
- preoperative warming by covering the child in a cotton blanket or using forced air warming system.[27,28] Moreover, the preventive measures have to be devised on the basis of available resources especially in developing nations by innovations and improvisations.[29]

3. ***Maintaining normothermia*** *in intraoperative phase by:*
   - maintaining ambient OR temperature □23□ C so as to reduce radiation and convection losses but it may be associated with discomfort to OR team.
   - induction of anesthesia should not begin unless and until the patient's temperature is 36.0°C or above.
   - use of warmed intravenous fluids[30] alone may not prove to be effective.
   - Passive insulation i.e. minimizing heat loss by insulating the child from the environment by using surgical drapes, cotton blankets and metalized plastic covers. The trapped air between the covers and child□□ s surface provides the insulation. Increasing the number of layers does not provide further protection .Reduction in heat loss is by approximately 30% and is directly proportional to the covered surface area.[30]
   - Active skin warming vs. passive protection.
     (i) *Forced-Air Warming Devices*- are the most commonly used and efficient active warming systems.[31] These consist of an electrically powered heater blower unit and blanket made of paper to cover the patient. It provides convective heating to keep body warm. To increase the efficiency, prewarming the child is desirable and the largest size of the blanket that covers maximum body surface is preferred.[32] These can increase the core temperature by almost 0.75°C/hour.
     (ii) *Resistive heating (electric blankets)* are cheaper and equally efficient as forced-air system.[34]
     (iii) *Energy Pads* use circulating heated water that comes in contact with patient's skin.
     (iv) *Circulating water mattresses* are placed over the operating table under the pediatric. This system maintains an acceptable efficiency in pediatric patients as it involves warming the back skin surface which provides larger surface area in children as compared to adults.
     (v) *Radiant warmers/ overhead heating units* generate infrared radiation. The effectiveness depends on the distance between the device and the skin of the patient and its direction. They can be used during induction of anesthesia until the child is covered with surgical drapes.
     Disadvantages of warming devices include the risk of burns seen when used incorrectly.[35] A combination of them increases treatment costs too.

Internal Warming Systems

Fluid warmers should be used for major surgeries with considerable blood loss and massive fluid shifts. Active and passive inspired gas humidification slightly contributes in maintaining core temperature in anesthetized pediatric patients. Active airway heating and humidification uses electric humidifiers and passive humidification involves using heat and moisture exchanger. These preserve cilial function and prevent bronchospasm. But recent SCIP[24] do not recommend their use.

CONCLUSION

In conclusion, during pediatric anesthesia infants and small children are prone to perioperative hypothermia due to many inherent factors. This makes it mandatory to monitor their core temperature. Management should involve prevention and/or decreasing the risk by use of a multimodal approach. This includes preoperatively keeping the child warm, increasing ambient OR temperature to 23 □-25 □ C, use of warm intravenous fluids, passive insulation and use of forced air warming devices.

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