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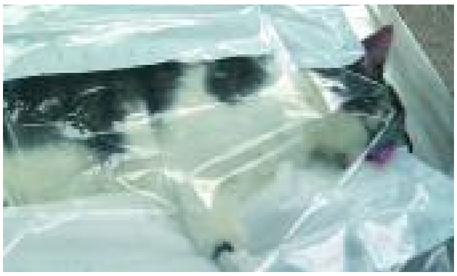


Perioperative Hypothermia in Veterinary Patients

Perioperative hypothermia is likely the most common complication associated with general and regional anesthesia with incidences reported from 60% to 90% of human and animal patients.[1,2] Although hypothermia has been used clinically in particular situations, subnormal body temperature is associated with a host of complications.

Most veterinary species are "warm-blooded" and maintain their body temperature within a narrow range. Normal rectal temperature in dogs is 39° ± 0.5°C (102° ± 1°F) and in cats is 38.5° ± 0.5°C (101.5° ± 1°F).[3] The normal range in body temperature (~0.5°C [1°F]) is known as the interthreshold range and body temperatures within this range do not trigger any thermoregulatory responses.

Core vs Peripheral Body Temperature

Core body temperature can be accurately measured at the tympanic membrane, nasopharynx, esophagus, and the pulmonary artery. Rectal temperature can more easily be measured but can lag behind changes in core body temperature. Skin is not a reliable indicator of core temperature as it is generally 2° to 4°C lower than core temperature.[4] This gradient from core to periphery allows the skin to act as a gate for heat dissipation and conservation. Arteriovenous anastomoses present in the skin are major contributors to thermoregulation. Dilation of these shunts allows for large amounts of heat to be lost to the environment from the core and, conversely, vasoconstriction of these shunts prevents heat loss from the core.

Thermoregulation

Thermoregulation is a complex interaction between thermal sensing, central processing in the hypothalamus, and behavioral and physiologic responses. Heat and cold thermal receptors have wide distribution throughout the body. Cold information is primarily transmitted along Aδ-fibers, whereas heat information is conducted along C-fibers. Afferent information is transmitted up the spinal cord to the hypothalamus, which coordinates the information.

The hypothalamus then "compares" these values with the threshold temperatures that trigger thermoregulatory responses (ie, those temperatures that are outside the interthreshold range). If the body temperature has exceeded the threshold temperatures (either above or below), a series of behavioral and physiologic responses will be triggered. Behavioral responses to decreasing body temperature can include a more compact posture or heat-seeking behavior (eg, sun seeking). Autonomic responses to declining body temperature include vasoconstriction in arteriovenous anastomoses and activation of the sympathetic nervous system, which increases thermogenesis. The ability to tightly control thermoregulation declines with age.

Types of Heat Loss

Heat loss is generally divided into 5 types: radiation, convection, evaporation, respiration, and conduction. Heat loss from radiation occurs when a hot object emits radiation waves. These waves carry energy (heat) away from the body and cause it to cool. Fifty percent of heat loss can be from radiation.[5] Losses from convection occur when the warmed air surrounding the body rises (due to heating) and is carried away from the body.

Radiation and convection are the most important causes of heat loss and can account for 80% of the total heat loss in a patient.[5] Evaporative heat loss occurs through evaporative cooling, which can increase with large surgical exposures. Respiratory heat loss occurs when gases are warmed and humidified by the body. Normally respiratory heat loss is less than 10% of total heat loss; however, during anesthesia the inspiration of dry cooled gases can increase such heat loss. Conduction losses occur by way of heat energy being transferred through a substance and normally accounts for minimal losses. However, metal surgical tables can increase heat loss through conduction. It should be noted that all types of heat loss are dependent on the amount of exposed skin. Thus, if skin exposure is minimized, heat loss can be minimized too.

Thermogenesis

Heat is produced primarily by increases in metabolism. Shivering can increase metabolic

continues

rate to 2 to 3 times normal and the release of thyroid hormones and catecholamines can also increase metabolic rate and contribute to thermogenesis. However, the increased metabolism comes at a cost, as it increases consumption of oxygen, adenosine triphosphate, and glucose.

Anesthesia and Thermoregulation

General anesthesia inhibits thermoregulation in a dose-dependent manner and routinely results in hypothermia. The effects of anesthesia on thermoregulation are multifactorial and include the loss of normal behavioral responses and the enlargement of the interthreshold range (up to 20 times), which alters the trigger at which normal thermoregulatory responses occur as well as the effects of anesthetic drugs. Opioids and propofol lower the threshold for shivering and many anesthetics (eg, volatile inhalants, propofol) cause vasodilation, which can further contribute to heat loss.

Regional anesthetics (blocks) also can lead to loss of thermoregulatory control due to vasodilation at blocked sites (potentially large surface areas), loss of ability to shiver, and altered thermal sensors at the blocked sites. Furthermore, in many patients sedation is used with regional blocks, contributing to loss of thermoregulation. In humans, the interthreshold range can increase to 3 to 4 times normal with regional anesthesia.[6]

Phases of Changes to Core Temperature

Loss of core body temperature occurs in 3 phases. The first phase occurs during the initial hour of anesthesia: there is a large drop in body temperature due to redistribution of heat from the core to the periphery, where it is then easily lost. Dogs without supplemental heat can lose almost 2°C in the first hour.[7] The second phase occurs over the next 2 to 5 hours. There is a slow linear drop in temperature due to the increase in heat loss compared to heat production. The final phase occurs late in the anesthetic period, approximately 3 to 5 hours after beginning anesthesia. A thermal plateau or steady state is reached in which core temperature remains fairly unchanged.[1]

Complications

Consequences of Heat Loss

Intentional hypothermia can be used clinically during surgery to minimize myocardial and central nervous system ischemia by decreasing basal metabolic rate and oxygen consumption.[8] However, unintentional hypothermia is associated with a host of unwanted and potentially life-threatening complications.

Immune System/Healing: Hypothermia impairs the immune system by decreasing oxidative killing by neutrophils, reducing phagocytosis, suppressing leukocyte migration, protein wasting, and decreasing synthesis of collagen. Furthermore, vasoconstriction and increased viscosity of blood decreases oxygen delivery to tissues, which can contribute to poor wound healing. In humans, hypothermia triples wound infection rates compared with those in normothermic patients.[9]

Hematology and Coagulation: Hypothermia causes an increased viscosity of blood and slows enzymatic reactions of intrinsic and extrinsic pathways. There is reduced platelet function and a reversible prolongation of coagulation times.[10] In humans, hypothermic patients lose more blood and require more transfusions than equally matched normothermic patients.[11]

Cardiovascular: Hypothermia decreases cardiac output, increases the concentration of norepinephrine, and causes vasoconstriction. With rewarming, increased capacitance (vasodilation) can unmask hypovolemia or relative hypovolemia and precipitate shock-like episodes. In dogs, arrhythmias are likely at a core body temperature of about 31°C and ventricular fibrillation is likely with temperatures below 30°C.[12]

Metabolism: Hypothermia is associated with decreased liver and renal blood flow. These effects result in decreased liver metabolism and renal excretion. The slowed metabolism of anesthetic drugs can lead to prolonged recovery times and the potential for relative overdosing.

Shivering: Shivering increases metabolism and can increase heat production by 500%. Although it is effective in raising body temperature, shivering increases myocardial oxygen demands and glucose needs; it also raises intracranial and intraocular pressure. Humans often describe shivering as the most unpleasant memory of their perioperative experience;[1] thus it is likely also distressing for animals.

Morbidity: Human studies have repeatedly shown that even mild intraoperative hypothermia is associated with increased time in the intensive care unit and total increased hospitalization times.[9] Although no veterinary studies have looked at the morbidity associated with hypothermia, it is reasonable to believe that similar increases in morbidity might occur.

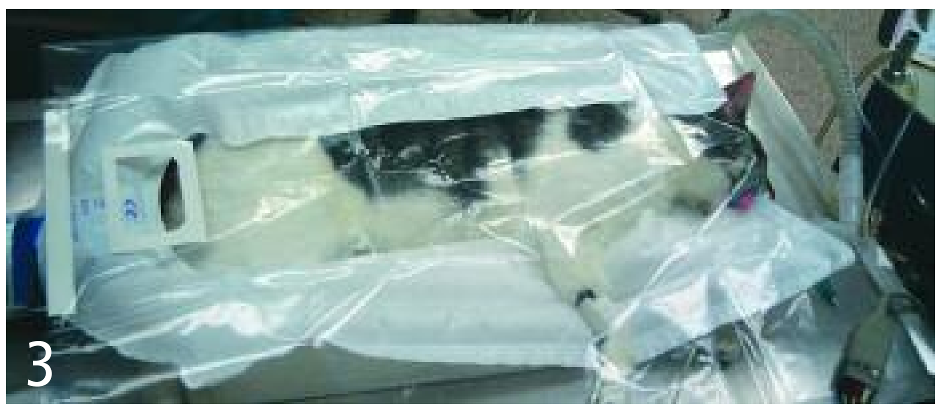
Oxygen Dissociation Curve: Hypothermia is associated with a left shift to the oxygen dissociation curve. This shift results in greater binding of oxygen to hemoglobin and less off-loading of oxygen at the tissue level. Poor off-loading in conjunction with vasoconstriction can potentially decrease tissue perfusion. As the patient rewarms, the oxygen dissociation curve returns to normal and more off-loading can cause a decrease in peripheral hemoglobin saturation.

MAC: Decreased body temperature is associated with a decrease in minimum alveolar concentration of volatile inhalant anesthetics. The decreased requirement for inhalants coupled with slowed metabolism can increase the risk of anesthetic overdose.

Acidemia: Poor tissue perfusion from vasoconstriction, decreased cardiac output, and shifting of the oxygen dissociation curve can result in anaerobic metabolism and the production of lactic acid. With rewarming, lactic acid from poorly perfused areas mixes with core blood and results in a systemic metabolic acidosis. Derangements in acid/base status can be detrimental if not monitored and addressed.

Prevention

Prevention of perioperative hypothermia is easier than treatment. Preinduction skin warming is the only way to prevent redistribution of core heat to the skin (redistribution hypothermia).[13]



Because the skin is the major source of heat loss during anesthesia, simply covering the skin can decrease heat loss by 30%.[2,14] Although conductive heat losses are generally small, patients placed on metal surfaces without a buffering layer may suffer significant heat loss even with additional heating sources. Warm ambient temperature can help maintain normothermia but can be uncomfortable for hospital staff. It is important to know which drugs can inhibit thermoregulatory responses. For example, meperidine can abolish shivering.

Treatment

Treatment of hypothermia should be directed at preventing further heat loss as well as providing active warming. Methods of preventing heat loss include covering of nonessential exposed skin, administering of warmed fluids, and warming the environment when possible. Blankets, plastic, metallic/reflective sheets, or a combination can be used to cover the skin.

Active warming of feet and legs has been shown to be more effective than warming the trunk.[2] Similarly, wrapping the feet with bubble or plastic wrap also can minimize heat loss. Heat and humidity exchangers can be used in the anesthetic circuit to eliminate the need for the body to warm and humidify cold dry anesthetic gases.

Active warming increases the total heat content of the body by the net transfer of heat via external heating sources, including forced warm air blankets (Bair Hugger; Arizant Healthcare Inc, www.arizant.com/arizanthealthcare), circulating warm water blankets, and heat lamps. Electric heating pads should not be used as they can be associated with thermal burns and significant morbidity.[15] Circulating warm water blankets are more effective when placed over the patient (**Figure 1**). Cotton or reflective blankets can be placed over circulating water or forced air blankets to increase insulation (**Figures 2 and 3**). Caution should be used with any heating source to assure that the patient cannot be burned or become dehydrated.

The transfer of body heat to cold intravenous fluids can contribute to loss of core body temperature. The amount of heat loss depends on the temperature and amount of fluid infused. Thus, warming intravenous fluids is recommended. In cases of extreme hypothermia, peritoneal and pleural irrigation with warm saline (40°-42°C [104°-107.6°F]) can effectively change core body temperature.[16] In humans, cardiopulmonary bypass has also been used successfully, with excellent long-term outcomes, to actively rewarm patients.[17]

Monitoring

Although hypothermia is common perioperatively, animals can become hyperthermic. Long-haired breeds or animals with thick undercoats can become hyperthermic from external heating sources or even from operating room lights or surgical drapes. Careful monitoring will identify animals that need more or less thermal support.

Conclusions

Perioperative hypothermia is more than an inconvenience. Decreased body temperature can derange the immune system, coagulation, metabolism, and perfusion. Decreased perfusion is due to changes to the cardiovascular system, oxygen dissociation curve binding, and loss of red blood cells due to altered coagulation. Individually or together, these changes can lead to increases in morbidity and mortality. Thus, significant physiologic and surgical complications can be avoided by careful monitoring and treatment of falling body temperature.

See Aids & Resources, back page, for references, contacts, and appendices.