Hyperthermia during anaesthesia

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Anaesthesia and surgery may have profound effects on the thermoregulatory system, and relatively small changes in body temperature may result in detrimental effects on cellular and tissue function. This makes body temperature perioperative monitoring very important, but unfortunately, it is not often routine.

Results of the Confidential Enquiry into Perioperative Small Animal Fatalities (CEPSAF) showed that temperature was measured in the postoperative period in only 11-14 per cent of small animal patients anaesthetised. This is disappointingly low, especially considering the ease with which this parameter can be monitored.

Nearly all our small animal patients become hypothermic during general anaesthesia due to their relatively large body-surface-to-volume ratio, combined with the depressant effects of the anaesthetic agents on the thermoregulatory system. However, during hot summer days, hyperthermia may be seen, especially in larger dogs with thick coats.

Hyperthermia is an increase in body temperature above the normal range for that species. It results from a loss of equilibrium in the heat balance equation, resulting in heat being produced or stored in the body at a rate that is in excess of heat dissipating through radiation, convection, conduction and evaporation.

The body can be divided into a core thermal compartment, comprising the head and trunk, and a peripheral thermal compartment, consisting of the extremities.

In general, metabolism is the only internal source of heat production. The brain and major organs in the trunk are the most metabolically active tissues and p r o d u c e more metabolic heat than muscles at rest. Within the core compartment, temperature is precisely regulated and rarely varies more than a few tenths of a degree Celsius. Depending on the environment, the temperature of the peripheral compartment may be several degrees less than the core body temperature.

Thermoregulation is primarily controlled by the preopticanterior hypothalamus, which receives input of afferent neurons from numerous sites in the body. In the hypothalamus, integrated body temperature is compared to thresholds – the temperatures at which specific thermoregulatory

responses are triggered. The interthreshold range is defined by those temperatures between which body temperature does not trigger thermoregulatory defence mechanisms (vasodilation and sweating or vasoconstriction and shivering), and is normally only 0.2°C.

Anaesthetic agents increase the interthreshold range approximately 20-fold from its normal value, and patients can become poikilothermic across a 3°C to 5°C range of core body temperatures.

In humans, the threshold for active vasodilation and sweating is only 1°C to 1.4°C higher during anaesthesia compared to individuals who are awake, while the threshold for shivering and vasoconstriction may be 2.5°C to 3.5°C lower compared to the awake state. Tolerance to heat is, therefore, lower than to cold and the body responds more aggressively to threats of hyperthermia than it does for hypothermia.

This explains why heat dissipation and hyperthermia prevention during anaesthesia may become so important.

Increased body temperature may be either controlled, when pyrogens increase the temperature set point in the hypothalamus (fever), or be uncontrolled, when an increase in core body temperature can be produced by drug-related impairment of thermoregulatory response mechanisms (malignant hyperthermia), or by excessive heat exposure (warm environment).

Hyperthermia is metabolically stressful and may result in impaired enzyme function, protein denaturation, coagulopathies and cell death. Mild degrees of hyperthermia are not harmful, and temperatures below 40°C generally do not require treatment. Cell damage starts at temperatures above 42°C, when oxygen delivery can no longer meet the requirements needed for the high metabolic activity.

Organs most susceptible to the harmful effects of hyperthermia are the brain, kidneys, heart and liver. Hyperthermia can be aggravated by inadequate fluid intake, which may result in dehydration.

Symptoms

The vasodilation triggered in response to the stress of warmth is not simply the absence of vasoconstriction, but an active and effective vasodilation resulting in increased heat dissipation. It has been demonstrated that the effect of hyperthermia on the peripheral vasculature causes a significant increase in blood flow. Because of the decrease in total peripheral resistance, tachycardia may be seen during anaesthesia, as well as arrhythmias. During anaesthesia, a patient may still show signs of increased respiratory frequency, or even panting, as a response to a raised body temperature. This may easily be mistaken for a light degree of anaesthesia.

Causes

Uncontrolled hyperthermia may be iatrogenic if the patient is excessively heated, such as by forced-air warming systems, heat pads, insulation blankets and the use of warmed fluids.

Well-insulated breeds with thick fur and fat may struggle to maintain a normal body temperature, especially during hot summer days and in a warm ambient environment. Brachycephalic breeds seem to be particularly predisposed to develop hyperthermia, as they often struggle with maintaining normal airways and are easily stressed.

Other potential causes of uncontrolled hyperthermia may be related to the choice of anaesthetic breathing system.

In a rebreathing system, heat is produced as a result of the chemical reaction between carbon dioxide and soda lime, which will warm up the gases within the breathing system. This effect may be exacerbated during lowflow anaesthesia. The use of heat and moisture exchangers (HME devices) may further increase the temperature of inspired gases.

Drug-induced hyperthermia is rare during veterinary anaesthesia. However, administering opioids can produce mild to moderate increases in body temperature in cats.

Opioids alter thermoregulation by resetting the threshold point controlled by the hypothalamus. The effects of opioids on thermoregulation are speciesdependent: morphine can produce hypothermia in rabbits, dogs and monkeys, and hyperthermia in cats, goats, cattle and horses.

In affected cats, body temperature at extubation is found to be inversely related to the degree of hyperthermia, with the coldest cats at extubation reaching the highest temperature during recovery. All types of opioids (pure mu-agonists, partial agonists and agonist/antagonists) have been related to this phenomenon in cats. Affected cats may show restlessness and excitement. Naloxone (0.01mg/ kg IM or SQ) has been shown to reduce body temperature to within normal range within 30 minutes. When untreated, temperature declines to normal values within five hours, and no apparent morbidity and mortality have been associated with it.

Although quite rare, the autosomal dominant inheritant condition of malignant hyperthermia has been described in dogs. Affected dogs have a mutation in the ryanodine receptor gene encoding the calcium release channels of the sarcoplasmic reticulum of skeletal muscles, resulting in excessive calcium release when stimulated.

Clinical signs are tachypnoea, hypercapnia, rhabdomyolysis resulting in hyperkalaemia, generalised muscle contractures, arrhythmias, hyperthermia and acid-base disturbances. The condition is not breed related. The outcome is often fatal and early detection is essential for successful treatment.

When malignant hyperthermia is suspected, the anaesthetic agent that is the triggering factor must

be removed. Switch off the vaporiser and replace the breathing system and soda lime canister for new ones or consider using a non-rebreathing system. Intravenous dantrolene sodium should be given at 4mg/ kg to 5mg/kg.

Supportive treatment includes fluid therapy, and management of the acidosis through ventilatory support and administration of sodium bicarbonate, if it is a severe case. Active cooling of the body should be initiated and hyperkalaemia monitored for, and treated, if necessary.

Detail about this condition is beyond the scope of this article, but a good review of malignant hyperthermia is available (Brunson and Hogan, 2004).

Treatment of hyperthermia

Mild degrees of hyperthermia (body temperature below 40°C) are not harmful to the patient and may represent an appropriate response to an underlying disease (fever or infection) and, therefore, may not require treatment. Cell damage starts when the body temperature is above 42°C, when oxygen delivery can no longer keep pace with the racing metabolic activity and increased metabolic consumption.

If hyperthermia is detected during anaesthesia, or body temperature is rising to upper normal limits, the following should/can be undertaken:

- terminate any active heating of the patient
- remove HME device
- increase fresh gas flow
- change rebreathing system to non-rebreathing system
- clip the coat
- place a fan
- spray alcohol over the foot pads
- administer cold crystalloid fluids intravenously
- administer cold water over the body surface
- use ice packs
- use cold fluids to lavage

In extreme situations, clipping the coat will provide a very effective way of cooling the patient. However, not every owner will appreciate this, and the benefit of clipping large amounts of fur must be outweighed against the potential upset of the owner. Care has to be taken with spraying alcohol over areas of clipped skin, because severe skin reactions may result; cold water is a better option. Water evaporating from the skin’s surface results in cooling, but, if the water is too cold it causes vasoconstriction that impedes heat loss from the core body compartment until the skin temperature is below 10°C, at which time massive vasodilation may occur and core temperature may decrease precipitously.

Ice packs will increase conductive heat loss, but again, be careful with too much cooling. Direct contact between ice packs and the skin is best avoided. Increasing the fresh gas flow in rebreathing systems will result in washing out any warmed, rebreathed gases, and another option is to exchange a rebreathing system for a non-rebreathing system. Lavaging the rectum or stomach with cold fluids, or an exposed body cavity during surgery, can be very effective in decreasing body temperature.

Although it is very rare, if a rapid increase in body temperature is detected during anaesthesia, which cannot be reduced to normal limits by active cooling, it is best practice to cease administering any volatile anaesthetic agent. The patient should be woken up, or the breathing system and soda lime canister changed and anaesthesia maintained with intravenous agents run as a continuous infusion. Administration of antipyretic drugs (paracetamol in dogs, NSAIDs) is generally effective for fever, but is ineffective for uncontrolled hyperthermia.

Further reading

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