Changes in Body Temperature during Anaesthesia

T. M. Mufti (Department of Anaesthesiology, A. M. College, Mil Hospital, Rawalpindi.)

Introduction

Variable degree of changes occur in body temperature during anaesthesia and surgery. Attenuation of normal homeostatic thermoregulation occurs during the course of anaesthesia and surgery, which may impose large thermal stress. In addition various other factors contribute towards these hypothermic changes, can be minimised by operating in warm theatre. Critical theatre temperature is about 2 1°C, warm intravenous fluids, metal foil reflective space blanket , cardiac output support, radiant heat cradle and woollen blanket etc. can be used. The changes in body temperature may be detrimental to the patient's status, therefore to understand the normal thermoregulation and the factors which may affect this process during anaesthesia is very important.

Physiology of Thermoregulation

Various bilogical reactions keep occurring in the body and tha velocity of these reactions, catalyzed by the enzymes increases with temperature to a maziamum, beyond wich enzyme activity decreases because of protien denaturation. Many biological reactions have a tenperature coefficient of 21 at 10 degree centigrade. In mammals, protein denaturation begins at about 42°C and internal temperature at or above this value can be tolerated only briefly. Vital organ functions become impaired at an internal temperature much higher than freezing e.g.,consciousness is lost in men at 30C because of ventricular fibrillation. Accurate mainteance of internal temperature close to the pptimum for enzymatice activity is much beneficial.

Homeothermy

It involves sensing the body temperature and driving the mechanisms controlling the heat loss and heat gains, so as to maintain the normal body temperature. Some degree of thermoregulation is mediated by behavioural responses despite much larger variations n ambient temperature. A pattern of temperature regulation in wich the cyclic variation in core temperature, either nycthermally or seasonally is maintaind within limits of + 2°C is called homeothermy.

Homeothermy is achieved by balancing heat gains with heat losses. Within a range of ambient temperatur this may be achieved without metabolic expenditure by control of peripheral vasculature. Beyond the limits of this thermoneutral zone between 20-35°C in resting adults, energy must be expanded in order to maintain the thermal balance.

Heat Gains and Heat Losses

Obligatory heat gains inculde, heat derived from basal metabolism, feeding, storage and growth. As the major source of metabolic heat is muscular exercise, walking results in a 3-5 folds increase in metabolc rate above basal and severe exercise can produce upto 20 fold increase. Facultative heat gains are available as means of restoring thermal balance by shivering and non-shivering mechanisms. Shivering produces 4-6 fold increases in heat production2 whereas non-shivering mechanisms of heat production produces 2-3 fold increase in metabolic rate e.g. by activation of brown fat in neonates. In humans older than one year, brown fat is probably unimportant as a source of heat production.

Heat is lost from the body only at points of contact with the environment, that is the skin and respiratory tract. Seventy five percent of the basal heat production is lost by convection, conduction and radiation from the body surface while the body is at rest and 25% losses occur by insensible perspiration and through respiratory tract in approximately equal amounts. Sweating is the major source of heat loss under thermoregulatory control; maximum sweat production can go as much as 5 litres in a day.

Heat Storage

The body is not in a continuous state of heat balance. Net heat gains and losses result in changes in the overall heat content of the body, normally with little or no change in the core body temperature, but changes in the temperature of body shell.

Temperature Receptors

These can be classified as central and peripheral thermoreceptors.

1. Central Thermoreceptors

Temperature receptors are located in the spinal cord, mid brain, the lower brain stem, abdominal organ and skeletal muscle. The concept of hypothatamus as a sole sensor of core body temperature has given way to one of the multiple thermal inputs with the hypothalamus contributing only 20%[2].

2. Peripheral Thermoreceptors

Warm and cold receptors exist in the skin. It has been suggested that cold sensitivity results from the actvity of an ouabain sensitive, sodium - potassium ATPase while warm sensitivity is attributable to the different temperature coefficient of sodium and potassium membrane permeabilities[2].

Cold impulses travel mainly in A-delta fibres and warm impulses in C fibres. Peripheral receptors also demonstrate accomodation and pattern of discharge is related to the rate of change of temperature[2].

3. Input-Output Coupling

Although the hypothalamus primarily performs the integration of thermal inputs and control of the effector organs , but still a certain degree of processing occurs in the spinal cord. It appears that thermoregulation utilizes loose input-output coupling, such that a given stimulus may provoke one of the different effector responses , e.g. stress of cold may result in the behavioural ‘response of selection of a warm environment or the autonomic response of shivering[2].

Anaesthesia And Temperature Regulation

Several factors combine together to interfere with normal thermoregulation during anaesthesia and surgery, e.g., changes in behavioural responses, attenuation of hypothalamic functions, reduced metabolic rate, reduced effector responses and abnormally large thermal stresses. Although the general anaesthesia totally abolishes the behavioral responses, still the local anaesthesia also impairs the behavioral responses to some extent.

General Anaesthesia

Loss of consciousness during general anaesthesia abolishes thermal sensations leaving the thermal receptors still sensitive. With the exception of Ketamine all general anaesthetics impair thermoregulation. There is a wider range of core body temperature over which no thermoregulatory responses occur. The thermoregulatory responses are still possible during anaesthesia as attempts at surface cooling causes shivering in a spontaneously breathing patient. The phenomenon of thermoregulation during anaesthesia has been rediscovered by observation of vasoconstriction in hypothermic and not in normothermic patients. Ketamine is

known to spare thermoregulation; similar is ether anaesthesia during which body temperature rises. Atropine has numerous thermoregulatory actions[3]. Inhalational anaesthetics and vasodilators redistribute heat to the peripheral tissues and increase the potential for heat loss to the environment. Opioids, barbiturates, .phenothiazines and butyro-phenones have both central and peripheral actions tending to decrease body temperature. Clinical experience suggests that vasodilatation during propofol induction is dose dependent, core temperature in patients who received intravenous propofol for anaesthetic induction was consistently lower than the one anaesthetised with sevoflurane[4]. Famotidine 20 mg as premedication is associated with intraoperative hypothermia[5]. Other agents like neuromuscular blocking agents abolish shivering, so paralysed patients cool more rapidly, related to some extent to the type of surgery. The initial heat loss is more rapid and the core body temperature decreases on induction of anaesthesia, with a slower reduction after one hour. Initial change occurs by redistribution of heat to the periphery but later loss of heat is because of loss to the surroundings, measured as approximately 0.3°C per hour or at a rate of 10 to 16 calories per hour[6]. Higher rate of heat loss has been observed in the elderly.

Local Anaesthesia

Although hypothalamic thermoregulation remains intact during regional anaesthesia still abnormal heat losses occur by vasodilatation, shivering and intravenous infusions of cold fluids. If the patient is not sedated, may complain of feeling cold and have shivering above the level of block. In a study, no significant change in aural temperature was observed when extradural analgcsia and four different techniques of general anaesthesia were compared during pelvic surgery. It has been suggested that stimulation of spinal cord thermoreceptors causes shivering, which is not thermoregulatory in nature. However rewarming during recovery is prolonged, because of decreased ability to shiver and continued heat losses[6].

Thermal Stresses

Cold operating theatres, skin preparation lotions, irrigating fluids,-intravenous fluids and cold dry anaesthesia gases combined with exposure of body viscera, all impose large thermal stresses on the patients.

Recovery

Unless active measures are taken to prevent shivering in the recovery period large increases in oxygen consumption occur leading to hypoxaemia. So to prevent shivering in the recovery period best is to avoid peroperative hypothermia. The simple way to avoid this hypothermia is skin rewarming with a radiant heater. Methylphenidatc and opioids are only partially successful in inhibiting shivering. In patients with limited cardiopulmonary reserve passive rewanning is done by postoperative paralysis and ventilation[7].

Measurement of Temperature

Various methods and sites can be used for temperature recording e.g. conventional clinical mercury thermometer, skin electronic forehead thermometer, thermistor probes with an accuracy of+0.1-0.2oC which is more than adequate in clinical setting[2].

Sites of Measurement

Body temperature is monitored during anaesthesia to ensure that thermal balance is maintained and to detect the onset of malignant hyperpyrexia . To document thermal balance adequately, it is necessary to record both core and peripheral temperatures in order to estimate whole body heat. One or two of the following measurement can be used.

1 . Nasopharyngeal: A thermistor probe in this position is a less reliable measure of cerebral temperature than correctally placed oesophageal probe[2]. Leakage of gases around tracheal tube

may influence the measurement.
2 . Oesophageal: The lower 25% of the oesophagus gives a reliable approximation of blood and cerebral temperature provided the thoracic cavity is not open. A distance of 24 cm beyond the comiculate cartilage has been recommended in adults[2]. This method is not suitable in awake patients.
3. Rectal: Although misleading , the rectum remains the most commonly used sites for measuring the core body temperature, commonly reads 0.5-1.0°C higher and responds slow to changes in body temperature so not suitable as a clinical monitoring during anaesthesia.
measurement but are expensive and inaccurate if the urine
4. Urinary Bladder: Temperature probes in the indwelling urinary catheters have been used to measure core body temperature. They are more accurate than rectal flow is less than 20ml per hour[8].
5. Tympanic Membrane: Tympanic membrane and aural canal temperature provide a rapidly responsive and accurate estimate of hypothalamic temperature and correlate well with oesophageal temperature[9]. Aural canal is the preferred site, probe is better tolerated, but there is risk of perforation to the tympanic membrane.
6. Blood: The thermistors of pulmonary artery catheters enable continuous measurement of blood temperature, the best estimate of core body temperature.
7. Skin: Measurement of skin temperature gives no information other than local site, where probe is placed.

Calculation and Assumptions

Mean Skin Temperature

Several different schemes for calculating mean skin temperature from individual measurements have been assessed during anaesthesia and in the recovery period. Accurate estimates of mean skin temperature require measurement at 10 or more sites. However when compared with 15 sites methods the four sites method of Ramanthan was found to have 95% confidence limits of 0.2°C at 33° C[2].

Total Body Heat

The heat content of a body is mean temperature x weight x specific heat. The specific heat of the human body is taken as 3.475KJ per °C (0.83 cal per °C) and the formula becomes: Total Body Heat = Mean body temperature x weight (kg) x3.475kg[2].

Methods used for control of body temperature during anaesthesia

Ambient Temperature

It has been demonstrated that if the operation theatre temperaure is maintained greater than 24°C, all patients remain normothermic during anaesthesia (oesophageal temperature 36°C) At ambient temperature less than 21°C, all patients become hypothermic while between 2 1-24°C, thirty percent patients become hypothermic. Besides temperature, humidity and air-flow are also important.

Humidifiers

The administration of dry anaesthesia gases which must be humidified in the lungs, results in a loss of heat from the body, which has been calculated as 6.45kj per hour/litre of minute ventilation. This loss of .heat can be totally prevented by adequate humidification of inspired gases. It has been proved experimentally that inspired gases fully saturated at 37°C results in a reduction in net heat of 10.6-16 call hour in man[6], so heat saving restores thermal balance during anaesthesia.
Most efficient heat and moisture exchangers are capable of delivering gases at 27°C and 85%

relative humidity with non-rebreathing systems and 99% relative humidity at 29°C with circle system. Humidified and adequately heated inspired gases offer a simple and effective way of restoring thermal balance during anaesthesia.

Heat and Moisture Exchangers (HMEs)

Heat and moisture exchangers humidify, warm arid filter inspired gas. Their incorporation into paediatric anaesthetic breathing system is recommended, dry anaesthetic gases cause greater heat loss in children than in adults as children have higher ratio of minute volume to body surface area[6]. However they can cause delay in the inhallational induction.

Anaesthetic Gas Delivery Systems

Use of a close circuit system is beneficial because it causes humidification and warming of inspired gases and there is less pollution of theatre atmosphere, resulting in economy of gases.

Warming Mattresses and Blankets

The most common variety of warming mattresses has water circulation through plastic tubings from a thermostatically controlled heater. These are not very efficient when used alone to counter heat losses during anaesthesia and surgery rather thermal injury may occur[2]. However combination of warming mattresses with a heater humidifier has been shown to be more efficient in preventing heat loss. A similar benefit has been demonstrated using unheated toweling to increase insulation of non operated parts[6]. Recently a hot air mattress has been introduced which claims to produce a warm microclimate under surgical drapes and is effective in reducing heat losses in children[11].

Radiant Heaters

These have been used extensively in the postoperative period to speed rewarming and to suppress shivering. The heat supply from an overhead radiant heater has been estimated as 74kJ per hour (17.7 callhr) and core temperature increases more rapidly towards normal with a radiant heater, achieving an additional benefit of suppression of shivering, decreased oxygen uptake, carbon dioxide production and peripheral vasoconstriction.

Oesophageal Rewarmers

These devices consist of a double lumen

oesophageal tube through which water is circulated at upto 42°C. They were originally designed for use in core rewarming of hypothermic patients, but have been used during anaesthesia[2].

Intravenous Fluids and Blood Rewarmers

Anaesthetized patients, especially children, are vulnerable to hypothermia. The infusion of one litre of fluid at 20°C results in a thermal loss of7l kJ (17 cal) as the body warms the fluids to 37°C. Similarly, transfusion of one litre of blood at 4°C requires about 125kJ (30 cal) for warming in the body. Such losses can be avoided if thermostatically controlled blood warmer is used with a setting not exceeding 40°C.

Extracorporeal Circulation[12]

It is highly effective in patients who have suffered severe hypothermia, (core temperature less than 28°C) major trauma,accidental hypothermia, like drowning. Such invasive technique may not be appropriate for patients with less severe hypothermia. In patients with moderate hypothermia, venovenous rewarming is significantly faster than standard methods[13].

Induction of general anaesthesia invariably leads to changes in body temperature,usually in the form of hypothermia, which develops in a characteristic pattern consistingof three different phases (1) an initial rapid drop in core temperature largely caused by an internal core to peripheral redistribution of body heal, (2) a slower linear decrease in core temperature that

results from heat loss exceeding metabolic heat production6 and (3) a core temperature plateau resulting from decreased cutaneous heat loss and constraint of metabolic heat to the core thermal compartment in patients who become sufficiently hypothermic to trigger thermoregulatory vasoconstriction[14].

Reduction of core body temperature to 34°C in most patients may occur on induction of anaesthesia if active measures to conserve heat are avoided, however reduction of core body temperature to 32°C is often difficult and requires alternative active methods of cooling. However chilled intravenous fluids should be avoided because heat transfers readily between the microcirculation and surrounding tissues. Various studies indicate that certain degree of hypothermia does occur during anaesthesia according to the drugs and the technique used even when the operating room environment is standardized. Studies by Hoerauf indicate that systemic vasodilatation may facilitate core to peripheral redistribution of body heat. Ozaki and colleagues indicate in their study that skin temperature gradient and vasodilatation persists throughout the period of anaesthesia with thermoregulatory inhibition leading to hypothermia[15].

Thermal balance during anaesthesia is as important as maintaining other vital signs like pulse, blood pressure,respiration, oxygenation and capnography of the patient. By Anaesthesia minimizing the thermal stresses imposed on the patient and by providing a warm operation theatre, adequately heated humidified inspired gases and warm intravenous fluids, a thermal balance can be achieved. Temperature monitoring is always desirable during major surgical procedures particularly when controlled hypothermic techniques are being used. Post anaesthesia period cannot be overlooked in this regard, as shivering is potentially dangerous especially in children and patients with limited cardiopulmonary reserve, so temperature monitoring should continue during this period and shivering treated by warming mattresses and blankets, warm air, radiant heating of the skin, administration of oxygen and opioid like pethedine[16].

References

1.Rodwell V. Enzymes. In: Harper HA (ed.). Review of physiological chemistry. 12th ed. Atlas: Lange Medical Pub., 1969, pp. 144.46.

2.Imree MM, Hall GM. Body temperature and anaesthesi. Br. J. Anesth., 1990;64:346-54.

3.Ozaki M, Sessler DI, Negishi C, et al. Atropine increases the sweating threshold in humans ~abstract]. Anesthesiology., 1996;85:A17 1.

4.Hoerauf KH, Wallner T, Akea 0, et al. Less core hypothermia when anaesthesia is induced with inhaled sevoflurance than with intravenous propofol. Anesth. Anal., 1 999;88:92 1-4.

5.Hirose M, Hara Y, Matsusaki M. Premedication with famotidine augments core hypothermia during general anaesthesia. Anesthesiology, 995;83: 1179-83.

6,Shanks CA. Heat balance during surgery involving body cavities: Intensive Care, 1975;3:114-I7.

7.Rodriguez JL, Weissmen C, Damask MC, et at. Physiologic requirements during rewarming, suppression of the shivering response. Crit. Care Med.,1983;11:490-97.

8.Bone ME, Feneck RO. Bladder temperature as an estimate of boy temperature during cardiopulmonary bypass. Anaesthesia, 1988;43:181-85.

9.Cork RC, Vanghan RW, Humphery LS. Precision and accuracy of intraoperattve temperature monitoring. Anesth. Anag., 1983;62:211-14.

10.Luchetti M, Pinga A, Gentili A, et al, Evaluation of the efficiency of heat and moisture exchangers during paediatric anaesthesi. Paediatr. Aneasth.,1999;9:39-45.
11.Hatch DJ. Paediatric anaesthetic equipment. Br. J. Med. Anaesth., 1985;57:672-84.
12.Keatinge WR. Hypothermia in alive or dead. Br. Med. J.. 1991;302:3-4.
13. Gentilello LM, Codean RA, Offner PJ. et al. Continuous arteriovenous rewarming: rapid reversal of hypothermia in critically ill patients. J. Trauma, 1997;32:316.
14.Kurz A, Sessler DI, Christensen R, et al. Heat balance and distribution during the core-temperature plateau in anaesthtized humans. Anesthesiology, 1995;83:491-99.
15.Ozaki M, Sessler Dl, Matsukawa T, et al. The threshold for thermoregulatory vasoconstriction during nitrous oxide/sevoflurance anaesthesia is reduced in the elderly. Anesth. Analg., 1997;84: 1029-33.
16.Macintyre PE, Pavlin EG, Dwersteg IF. Effects of meperidine on oxygen consumption, carbon dioxide production and respiratory gas exchange in post anaesthesia shivering. Anesth. Analg., 1987;66:75l-5.