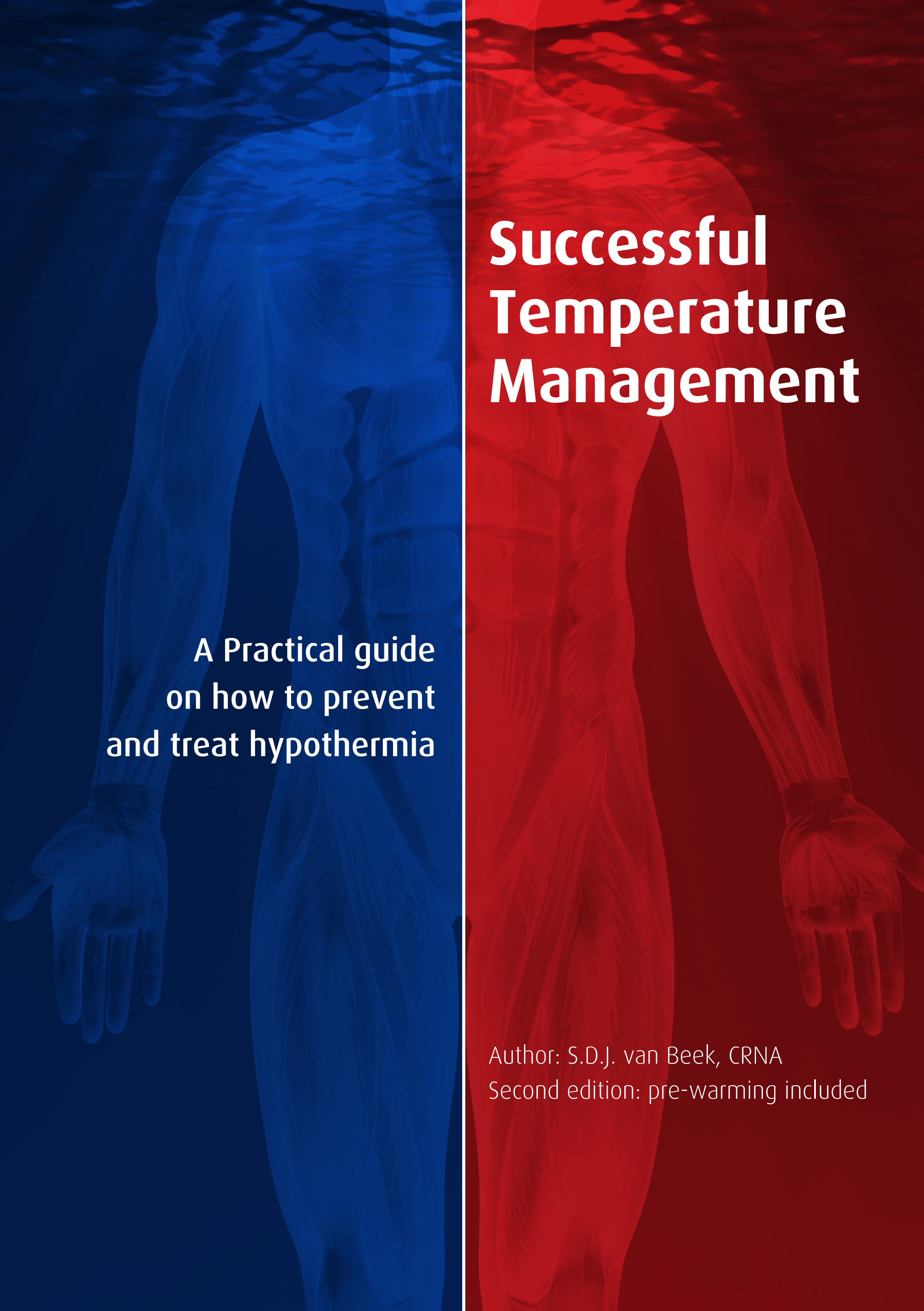

Successful Temperature Management

A Practical guide
on how to prevent
and treat hypothermia

Author: S.D.J. van Beek, CRNA

Second edition: pre-warming included

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Second Edition – 2013

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Foreword

International interest in avoiding inadvertent peri-operative hypothermia (IPH) has grown in the last 5 years, since the publication of the NICE guidelines in the United Kingdom. This handbook has been written by an author who has had a long-standing interest in this field of anaesthetic practice. He is passionate about sharing his knowledge and gives the reader succinct insight into the reasons why IPH is such a common phenomenon in our operating theatres.

The book covers the physiology of hypothermia and why it occurs during anaesthesia. It goes on to look at which groups are most at risk of IPH, what the potential consequences could be, and finally the best methods of preventing it occurring.

Recent research has concentrated on the concept of 'pre-warming' patients, since this is possibly the only approach that will ensure patients' core temperature will not simply redistribute to the periphery following induction of anaesthesia or onset of regional blockade. This modality is given ample coverage and the reader will no doubt wish to try it out within their own practice after reading this chapter.

Anaesthesiologists are known for their love and knowledge of physiology and they enjoy using this understanding to improve patient care. I therefore challenge all practising clinicians to determine the incidence of IPH in their own patients and subsequently, having read & digested the contents of this book, to change perhaps one aspect (or more if necessary!) of the routine care they give. I suspect that even small changes – such as turning on the fluid warmer in the anaesthetic room before too much unwarmed fluid is given, or making sure that the forced air warmer is set to maximum as soon as possible after induction – will make each anaesthetic they give slightly better.

When 'better' becomes 'routine' in terms of patient care then 'best' might follow and then the battle is won!

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Preface author

There was a time when accidental hypothermia in the surgical patient was accepted as something that we simply had to learn to live with, but in recent decades new techniques have been developed which improve the chances of controlling this complication.
We do not know exactly how many patients are hypothermic after an operation - many different figures have been reported. It is also the case that the temperature at which one speaks of hypothermia is not the same in all centres. It is, however, a fact that many patients have an excessively low core temperature post-operatively, and that this is a potentially dangerous situation.
Hypothermia is linked to a variety of physiological complications, including vasoconstriction, coagulopathy, ischaemic tissue damage, a reduced metabolic rate, angina pectoris, myocardial infarction and Arrhythmias'. In addition, hypothermia has been linked to post-operative wound infections and increased blood loss. Complications of this type also result in increased costs since the patient may remain in an ICU or hospital for longer. The acquisition of new equipment, in conjunction with making people aware of the problem of hypothermia, demands the input of some time and money, but this is certainly outweighed by the benefits. The anaesthesia team must strive for optimal thermal management so as to guarantee normothermia.
The concept of temperature is much more complex and more profound than appears at first glance. I have endeavoured to amass a large number of experiences, data and studies to provide a set of guidelines for everyone whose work entails dealing with hypothermia. Every hospital or clinic will of course have its own protocols, but the important thing is that everyone should remain constantly aware of the problem of hypothermia in the Pre-, Per- and Post-operative phases.

September, 2013

Bas van Beek, CRNA
Winterswijk, The Netherlands

Contents

[1.] Anatomy and physiology of the temperature regulating system

1.1 Core and Peripheral

The core temperature of mammals must always remain constant. This guarantees physiological homeostasis, since changes in core temperature can lead to a deterioration of vital functions. There are various mechanisms responsible for the balance between heat production and heat loss, ensuring that core temperature remains constant. Organisms that regulate their own body temperature are referred to as homeothermic. The average core temperature of a human being is between 36.5ºC and 37.5ºC. We call this normothermic. This temperature refers to the temperature central within the body: the core temperature. The temperature of the surrounding structures is called the peripheral temperature.

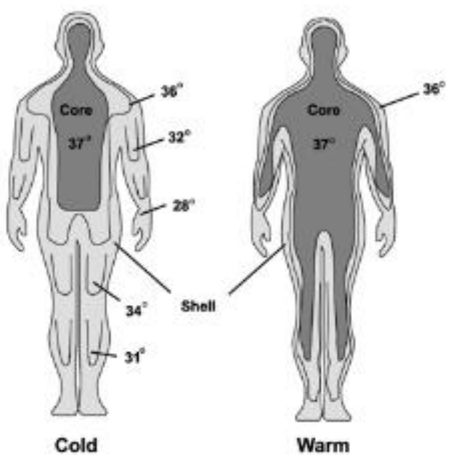


Figure 1: Difference between core and peripheral temperatures

A constant core temperature is important for the optimal function of physiological enzyme systems and processes within the human body. There must therefore be equilibrium between the amount of heat produced and the amount lost.

1.2 Thermosensors

The human body receives information about fluctuations in peripheral temperature from thermosensors, which are subdivided into specific cold sensors and heat sensors. The heat sensors are distributed over the skin, hands and face, and in the mucous membranes of the oesophagus, mouth and nasal cavity. These heat sensors are small, spiral organs consisting of free nerve endings that are located in the dermis. These organs are stimulated by a rise in temperature. The cold sensors are located much nearer to the surface, in the epithelium. There are also cold receptors in the oropharynx and cornea. The cold sensors are called Krause's corpuscles (corpuscular bulboidea). They are stimulated by a fall in temperature. There is an average of 25 cold sensors and three heat sensors per 50 tactile points. The thermoreceptors thus react to changes in temperature. The stimuli are transmitted via the sensory nerves to the temperature regulating centre in the anterior hypothalamus. The caudal part of the hypothalamus controls the sweat glands and muscles via the brainstem, bone marrow and efferent nerve fibres. In this way, via a complicated system of stimulus transfer, the observed stimulus results in a reaction. There are also central thermosensors: these obtain their information regarding the temperature mainly from the circulating blood. This information is also sent to the anterior hypothalamus, and processed by the caudal part. A rise in human body temperature results in vasodilatation in the skin and sweating, thereby allowing heat to be dissipated. A drop in human body temperature results in vasoconstriction in the skin and shivering. This system of thermoregulation aims to maintain a constant core temperature.

1.3 Temperature fluctuations due to physiological processes

As well as local temperature differences due to local metabolic activity and the degree of perfusion, core temperature may fluctuate secondary to various physiological processes:

- During exercise, the temperature rises in proportion to the amount of exercise.
- During ovulation, the temperature can vary by half a degree.
- The circadian rhythm can also cause half a degree of variation (particularly pronounced in the elderly).

1.4 Heat regulation

When heat loss and heat production are in equilibrium, the core temperature remains constant. When they are not, the core temperature varies.

This can take place in two ways:

- The core temperature rises. During exercise, heat production is increased but heat loss does not increase immediately. In case of fever, heat production is increased.
- The core temperature falls when the heat loss is greater than heat production and the human body is unable to compensate this loss immediately.

The human body has two systems that regulate temperature:

- The physical system
- The chemical system

Both systems react, independently or in tandem, by means of internal heat transport and the release of heat to the external surroundings. The internal heat transport has both an active and a passive component. Passive transport is a mechanism that transports heat from the deeper internal organs to the surface of the skin. This is connected with the metabolic activity and heat production in the organs concerned. Tissues with a lower metabolic activity have a lower temperature than tissues with a higher metabolic activity. The release of heat takes place as follows: the blood absorbs the heat from the core and releases it to the periphery. Blood flow rate, vasoconstriction and vasodilatation in the skin, and cardiac activity play a role in this process. The skin thus functions as a kind of radiator and there is a temperature gradient between the core and the periphery of the human body.

1.5 The physical system

The physical system depends on the following processes:

- radiation
- convection
- evaporation
- conduction

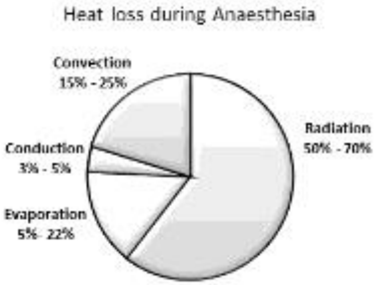


Figure 2: Heat loss during anaesthesia

1.5.1 Radiation

During radiation, a human body that is in the neighbourhood of a cold object loses heat to this object via its own infrared radiation. The amount of heat lost depends upon the human body's surface area and the temperature gradient between the human body and the surroundings. Radiation accounts for 50% - 70% of total heat loss.

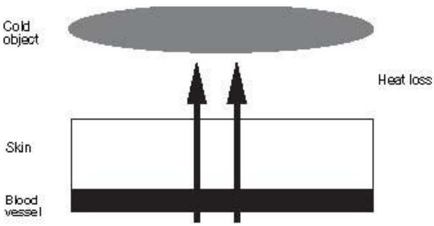


Figure 3: Radiation

1.5.2 Convection

Convection is a process during which heat is transferred to a passing stream of air. An important role in this process is played by the temperature of the surroundings, the rate of air flow, and the size of the exposed surface area. Approximately 15% - 25% of total heat loss is due to this phenomenon.

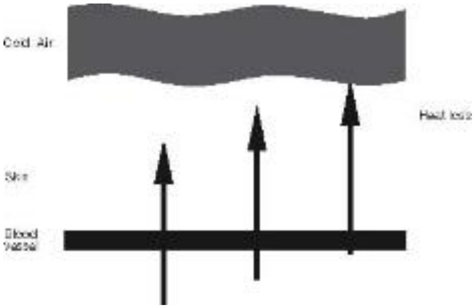


Figure 4: Convection

1.5.3 Evaporation

In general, we lose heat via the evaporation of fluids, such as sweat, the respiratory tract (breathing) and the mucous membranes. This evaporation accounts for 5% - 22% of the total heat loss. Any open human body cavities can also massively increase evaporative (and other) heat losses.

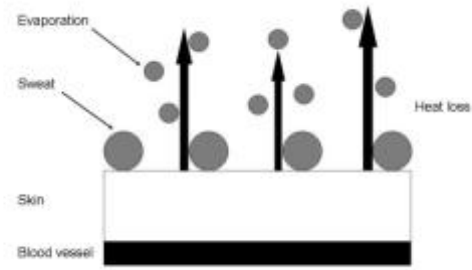


Figure 5: Evaporation

1.5.4 Conduction

During conduction, heat loss is brought about by the transfer of heat to objects with which the human body is in direct contact. The amount of heat transferred depends upon the contact surface area, the temperature gradient between the skin and the object, and the conductivity of the object. Conduction accounts for 3% - 5% of the total heat loss. Any cold fluids administered to a patient are also classified as conductive heat losses since the heat is transferred to the cold fluid after their administration.

Figure 6: Conduction

Physical temperature regulation attempts to minimize fluctuations in core temperature with the aid of the above processes. In conscious patients they will use behavioural adaptation to maintain temperature by adjusting their clothing or altering their environment accordingly. The release of heat is increased by vasodilatation and transpiration. A decrease in heat loss is achieved by mainly achieved by vasoconstriction of the blood vessels in the skin. The primitive or vestigial reflex known as horripilation (or goosebumps) has no actual effect on thermoregulation in humans.

1.6 The chemical system

When heat production is less than heat loss, the metabolism must be stimulated in order to increase heat production. This takes place via chemical reactions, i.e. heat production in the mitochondria due to increased activity, e.g. in muscles. The temperature regulating centre in the hypothalamus reacts to any decrease in core temperature by initiating various activities. One of the most important sources of heat is the muscles: their usual function is to bring about movement, accompanied by the release of heat.

At rest or in a cold environment, however, muscular metabolism is an important source of heat. Other activities that raise the core temperature include:

- Vasoconstriction in the skin in order to minimize heat loss.
- Increased activity of the sympathetic nervous system, thus stimulating catabolism: this is accomplished via increased secretion of adrenaline from the adrenal medulla and increased secretion of glucagon from the pancreas (glucagon promotes the transformation of glycogen into glucose).
- The reticular formation being stimulated, thus increasing muscular tone, which increases the production of heat.
- The individual endeavouring to overcome the cold by means of voluntary contraction of the muscles, such as by stamping the feet and rapidly crossing the arms over the chest.
- Stimulation of the cold sensors in the skin can lead to reflex responses, such as shivering and chattering of the teeth.
- An increase in thyroid activity: the secretion of TSH (thyroid stimulating hormone) is stimulated; this increases the basal metabolic rate. However, this has an effect only in the long term, for example when the human body adjusts to a permanently lower environmental temperature.

Subcutaneous fat and clothing also affect temperature regulation. Adipose tissue inhibits the passive transport of heat from the core to the skin, and clothing inhibits the transfer of heat from the surface of the skin to the surroundings.

[2.] What is hypothermia?

2.1 Definitions

Normothermia	Under normal circumstances, the core temperature is 36.5-37.5°C. This situation is maintained by the set-point in the hypothalamic thermoregulatory centre.
Set-point	The thermostat of the human body sees to it that the ideal temperature 36.8-37°C is maintained. The biorhythms account for a 0,6°C variation.
Fever or pyrexia	An increase in core temperature as a result of a pathological change in the set-point of the hypothalamic thermoregulatory centre.
Hyperthermia	An increase in core temperature as a result of an overproduction or decreased loss of heat, even though the hypothalamic thermoregulatory centre is functioning normally. > 37.5°C.
Hypothermia	A decrease in core temperature as a result of exposure to cold. The hypothalamic thermoregulatory centre is still functioning normally. Hypothermia can also be the result of a change in the set-point of the hypothalamic thermoregulatory centre due to a disease or drugs. Conventionally this is regarded as < 36.0°C in the peri-operative period.

2.2 Induced hypothermia

Induced hypothermia is a state of controlled low core temperature that is usually induced intentionally, in combination with a form of anaesthesia, to protect sensitive tissues against hypoxia and the tissue damage that can occur during certain operations and/or pathological clinical conditions. There are two types of therapeutic hypothermia: general medical and peri-operative/surgical.

Medical indications for active cooling and/or preventive mild hypothermia:

- anaesthesiological complications such as malignant hyperthermia.
- following cardiac arrest in order to reduce the chance of neurological damage.

Surgical indications:

- cardiac surgery
- neurosurgery

2.3 The degree of hypothermia

Depending on the magnitude of the decrease in core temperature that is aimed at, we speak of:

- mild hypothermia (33-35°C)
- moderate hypothermia (28-32°C)
- deep hypothermia (below 28°C)

These values are not set in stone; various limits are described in the literature.

2.4 Techniques

There are a number of techniques for achieving a particular degree of hypothermia:

- administering a cold fluid bolus can initiate the process.
- surface cooling: here, a patient under general anaesthesia is placed in a cold environment or actively cooled by means of a cold-water mattress or ice and a fan. The anaesthetic/sedation technique must provide for peripheral vasodilatation and shivering must be prevented.
- specialised adhesive cold packs can be used (hydrogel coated pads)
- intravenous heat exchange catheters are excellent but expensive
- extracorporeal cooling: the blood is withdrawn from the circulation and cooled with the aid of a heart-lung machine.
- intranasal cooling has recently been introduced.

2.5 Accidental hypothermia

Accidental hypothermia is an undesirable decrease in core temperature as a result of exposure to a cold environment or the inability of the human body to maintain the normal core temperature. This can also be a result of general and/or regional anaesthesia. It is therefore an anaesthetic complication.

The drop in temperature may already begin pre-operatively as a result of:

- a cold bed and transport.
- insufficient clothing or thickness thereof.
- cool rooms.
- vasodilatation as a result of the premedication.

- the administration of sedative premedication, particularly in a cold environment; the patient can fall asleep and not keep themselves insulated.

A patient can also lose heat peri-operatively as a result of:

- insufficient environmental temperature (from the point of view of the patient), due especially to severe convection (due to the laminar flow around the operating table).
- the nature, place and duration of the intervention.
- infusion of fluids that are below core temperature.
- the administration of a regional anaesthetic; causes intense vasodilatation
- irrigation with fluids that are below core temperature.
- artificial respiration with cold gases (this would seem to be marginal with low-flow respirators.
- the lack of use of Heat and Moister Exchanger (HME) or virus filters.
- the absence of muscular movements in the patient.
- thermoregulatory vasoconstriction threshold is affected by all anaesthesia and it is this that is responsible for the vasodilatation seen peri-operatively. The effect of drugs and their vasodilatation compounds this problem.
    - leaving parts of the human body uncovered, for example the infusion arm.

We have already seen that radiation, convection, evaporation and conduction play a role in the maintenance of temperature. In addition, one must be alert to the drop in temperature that occurs between the end of the operation or anaesthesia and the arrival of the patient in the recovery room. This drop in temperature must not be ignored. It can be ascribed for the most part to the fact that the coverings are removed (so that the patient is left uncovered) and the heating equipment and/or heating materials are dispensed with. “The best way to cool a man is to give him anaesthetic” (Pickering 1956).

[3.] The effect of hypothermia on physiological functions

Hypothermia affects the function of all organ systems. The changes that occur depend on the magnitude of the decrease in temperature. Temperature below 34 °C are not seen per-operatively

Core temperature	Symptoms
36°C	Normal core temperature
35°C	Vasoconstriction (peripheral), maximal shivering, speech disorders and hyperreflexia
34°C	Still conscious, but movements are difficult
33-31°C	Retrograde amnesia, no shivers, hypotension and dilation of the pupils, Atrium Fibrillation
30-28°C	Loss of consciousness, muscular rigidity, bradycardia and bradypnea
27-25°C	Loss of reflexes, ventricular fibrillation and cardiac arrest
17°C	iso-electric ECG

3.1 Circulation

Cold has a negative effect on the heart, with a clear decrease in heart rate, stroke volume and cardiac contractility. At the same time, the irritability of the myocardium is increased. In the absence of preventive measures, the heart tends to develop morbid cardiac events, while at temperatures between 27°C and 25°C there is an increased chance of ventricular fibrillation and circulatory arrest.
Even an increased risk of adverse cardiac events with moderate hypothermia. A study shows that catecholamine's (mainly norepinephrine) are increased when a patient is woken from a general anaesthesia with low temperatures. This explains the hypertension and bradycardia. Per-operative hypothermia is however used for cardiac protection. It should be stressed that it is the core temperature on emergence from anaesthesia that is important in these patients.

3.2 Respiration

Hypothermia depresses the respiratory centre. During mild hypothermia, the frequency of respiration and the tidal volume increase, but the dead space is increased due to dilatation of the airways. As the temperature drops further, the minute volume and frequency of respiration decrease until apnoea sets in. The production of CO_2 decreases, while the solubility of CO_2 in the blood is increased. The solubility of oxygen in the blood is also increased, enabling the tissues to withdraw less oxygen from the blood.

3.3 Endocrine system

At a temperature of 30°C, hyperglycaemia develops due to a delayed uptake of glucose by the cells and decreased excretion of glucose by the kidneys.

3.4 Liver

As the temperature drops, the liver progressively loses its detoxifying ability. At 30°C, hyperglycaemia develops. At 28°C, the metabolic capacity is decreased to 40% of normal. We also see an increase in the synthesis of lactic acid and a decrease in its catabolism.

3.5 Kidneys

Hypothermia can cause the inhibition of release of antidiuretic hormone and decrease oxidative renal tubular activity, causing diuresis and volume depletion. Cold diuresis develops, resulting in Na^+, K^+, Mg^+ and Phosphate excretion; supplements have to be given.

3.6 Electrolytes

Changes in potassium and magnesium levels are critical. A cold heart is more sensitive to changes in these levels, so that rhythm disorders can easily occur.

3.7 Drugs

There are considerable effects on drugs e.g. volatiles are more soluble at low core temperatures so patients can take longer to wake up. Fentanyl and Propofol metabolism is affected and it has been shown that Bispectral index Monitor (BIS) output decreases by about 2 for each degree drop in temperature. Muscle relaxants can also last up to twice as long with small drops in core temperature.

3.8 Blood and blood coagulation

Blood coagulation is disturbed due to a decrease in the activity of the clotting factors. There is an increased tendency toward bleeding due to platelet function being affected although actual platelet numbers do not drop until severe hypothermia is encountered (hypothermic thrombocytopenia). The clotting screen is rarely affected with mild hypothermia although it can be prolonged with profound cooling. The haematocrit may be elevated due to dehydration and splenic contraction and plasma viscosity has been found to increase as the core temperature falls below 27°C The viscosity of the blood is thus increased, with an increased risk of slugging (cell agglutination) in the microcirculation. Evidence has shown that patients are more likely to need a blood transfusion if allowed to cool per-operatively. Achieving temps of 36.5°C (rather than being content with temperatures of 36degC) may be even more beneficial.

3.9 Central nervous system

The cerebral blood flow decreases by 7% for each degree of decrease in core temperature. Hypothermia leads to impaired conduction in the nerves. At 33°C there is a loss of higher cerebral functions and retrograde amnesia. A human being loses consciousness between 30°C and 28°C.

3.10 Gastrointestinal system

At a temperature of 30°C, hyperglycaemia develops due to a delayed uptake of glucose by the cells and a decrease in insulin secretion. Shivering, if prolonged, may also cause hypoglycemia, as glycogen stores may become completely depleted. Hypoglycemia also may be an initial laboratory finding in patients who have been exposed to long-lasting physical endurance and exhaustion and often can be noted in alcoholic patients, who already may have depleted glycogen stores.

3.11 Immunosuppression

There is a greater risk of infection, up to three times that in a normothermic patient. Studies have found a threefold increase in post op infection following IPH.

3.12 The effect of hypothermia on a person's sense of well-being

Hypothermia affects a patient's shivering mechanism. As a result of the shivering induced by hypothermia, basal oxygen consumption rises; this can reach 400% of normal. At any rate this increase results in a greater load on the cardiopulmonary system. Shivering also has a negative effect on the experience of pain.

[4.] Temperature monitoring

There are various places where we can measure temperature: oral, nasopharyngeal, oesophageal, rectal, in the bladder, tympanic, axillary, via the blood.

Measuring site	Advantages	Limitations
Oral	Easy on awake patients	No trend monitoring possible. Golden standard closet to Swan-Ganz
Nasopharyngeal	Easy to introduce	Measurement errors due to leakage of air; nosebleeds; the core temperature is not measured
Oesophageal	Reliable	Dislocation; gastric catheters
Rectal	Easy to introduce	Not always accurate; the faeces act as insulation; the core temperature is not measured
In the bladder	Can be used during both general and locoregional anaesthesia	the urine flow affects the temperature but not much; can get a small delay in readings
Tympanic	Can be used during both general and locoregional anaesthesia	potentially traumatic; unreliable if not inserted by an expert
Axillary	Easy to introduce	only moderately reliable; the core temperature is not measured
Via the blood, tip of a Swan-Ganz catheter or CVC, the pulmonary artery	The core temperature	only during invasive pressure measurement

[5.] Hypothermia: groups at risk and risk factors

5.1 Groups at risk

The following groups run an increased risk of developing hypothermia:

- Children: due to the unfavourable ratio between human body volume and surface area.
- Elderly patients: due to decreased vasoconstrictor ability, the reduced compensatory capacity of the heart, reduced muscle volume and dysfunction of the hypothalamus.
- Cachectic persons: due to their poor general condition, muscle atrophy and anaemia.
- Patients with hypoglycaemia and hypothyroidism: due to a lower metabolic rate.
- Patients that are intoxicated: alcohol produces vasodilatation, so that the human body loses a great deal of heat.
- Patients with Raynaud's disease: these patients already have cold extremities.
- Patients with burn trauma: due to the (large) wound surface area, they lose (a large amount of) moisture via evaporation. These wound surfaces are also often exposed during treatment.
- Trauma patients: it is often the case that these patients' core temperature will already be low when they arrive in the emergency ward and are often given cold fluids. During triage and treatment they often remain uncovered.
- Thanks to a thicker average adipose layer and a more favourable morphology, women have better heat insulation.
- After a sedative premedication, patients inadvertently left in a cold environment will not adapt to the environment so could become more poikilothermic and therefore hypothermic.

5.2 Risks during anaesthesia

The induction of anaesthesia is an enormous risk factor for hypothermia. After all, general anaesthesia produces inhibition of the thermoregulatory centre as well as vasodilatation and muscle relaxation. During local or regional anaesthesia, there is limited vasoconstriction in the non-blocked region, accompanied by marked vasodilatation in the blocked region until the effect of the block has worn off. On balance, loco-regional anaesthesia also results in hypothermia.

Other risk factors include:

- The environmental temperature: 16-18°C is a pleasant temperature to work at, but a patient requires 24-26°C in order to combat hypothermia.
- The duration and nature of the surgery: a decrease in temperature by 1.5°C during the first hour, followed by 0.5-1°C per hour in the absence of measures to prevent hypothermia until the patient reaches a core temperature of 34°C. This will be followed by a so called 'plateau' phase.
- Infusion of cold fluids: we could state that 1 litre at room temp drops a 70kg patient temperature with 0.25°C.
- Artificial respiration with dry cold gases (high flow) and the introduction of gas into the abdomen.
- Opening and irrigation of human body cavities and/or other areas undergoing surgery: TUR patients in particular run a significant risk of developing hypothermia.
- Disinfection of the area undergoing surgery.
- Leaving parts of the human body uncovered, for example the infusion arm.
- Termination of a bloodless period that has lasted longer than one hour. At the moment of termination, blood again flows into the cold extremity, as a result of which it cools off. This in turn results in a decrease in core temperature.

5.3 Heat loss in the clinical context in relation to the physical processes

	radiation	conduction	convection	evaporation
Uncovered human body surfaces Anaesthetics (vasodilation agents)	✓		✓	
Cold OR equipment, e.g. operating tables	✓	✓		
Air conditioning	✓	✓	✓	✓
Cold IV fluids, blood		✓	✓	
Cold irrigation fluids		✓		✓
(Artificial) respiration				✓
Open human body cavities	✓			✓
Disinfectants		✓		✓
Wet gauze		✓		✓
Cold anaesthesia gases			✓	✓

[6.] Measures for the prevention and correction of hypothermia

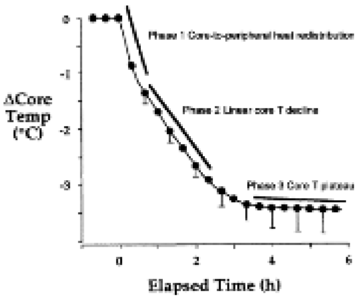
The best thing, of course, is to prevent hypothermia. We can accomplish this via either active or passive heating techniques.

6.1 PRE-WARMING

6.1.1 Introduction

Pre-warming is a way to store energy by offering the patient active heating prior to the surgery. The reason for pre-warming is that it is the most effective way to prevent redistribution hypothermia [a].

Figure:



Increasing the mean skin temperature can be done through a rapid transfer of heat to the patient. A temperature increase in the peripheral compartment helps to minimize the normal core-to-periphery temperature gradient and causes pre-induction vasodilation; heat flow to the periphery during anaesthesia is limited. To achieve this temperature increase, active warming devices, such as forced air warmers, must be used in the holding area or in the operating theatre.

The incidence of intra-operative or post-operative hypothermia has been found to be significantly lower in pre-warmed patients. The benefit for normothermic patients who are at high risk of developing hypothermia and its complications should be addressed. The American College of Surgeons recommend pre-warming for all patients who undergo surgeries expected to last longer than 30 minutes.

If there is no routine pre-warming protocol for all surgical patients, it is recommended to select pre-warming for those patients who will benefit the most. Hypothermia is frequently observed in post-operative patients transferred to the intensive care unit (ICU), mostly after undergoing large surgical procedures (AAA, Thoracic or Oncology surgery) or underlying medical disorders associated with limited physiological reserve. Critically ill patients are also expected to be particularly susceptible to hypothermia complications, such as peri-operative cardiac events, surgical site infections, and transfusion-related complications.

Pre-warming decreases the distribution of body heat through two mechanisms:
- By increasing skin temperature the core-to-peripheral-temperature gradient decreases
- Application of external heat results in vasodilatation, the post-induction vasodilatation due to the anaesthetic drugs will have less effect on the core temperature

6.1.2 How to pre-warm?

To prevent or reduce this redistribution hypothermia, the core-to-periphery temperature gradient should be as small as possible. In other words the skin temperature should be as close to parity with the core temperature. The arms and legs in particular should be covered. These human body parts, where additional heat can accumulate, play an important role in preventing and reducing redistribution hypothermia.

Optimal duration and temperature of pre-warming may differ among patients, but clinical findings have indicated that the heat provided during a 30-minute period of forced air warming at 40°C to 43°C generally exceeds the amount of heat redistributed during the first hour of general anaesthesia. From a practical point of view the pre-warming should be as short as possible. A recent study shows that 10 to 30 minutes of active cutaneous warming with forced air warming has proven to be effective. Higher room temperature and insulating materials can help to reduce/stop heat loss during this period and so be beneficial to store heat.

It is important to cover the skin surface as much as possible. So cover the patient completely, except for the face. In general start to pre-warm as soon as the patient arrives in the pre-operative holding area. Warming has to be continued until the patients are transferred to the operating room. During transport the patient should be covered with good insulating materials so the heat will be stored. This insulating strategy has to be continued until the patient arrives at the operating room. Control of a patient's core temperature should commence on arrival in the pre-operative holding area; patients can be insulated or actively warmed depending on the type of procedure or condition.

It has to be stated that active warming should not be stopped during the surgical procedure. Pre-warming by forced air warming is the most effective way to get a good result.

Conclusion:

- Pre-warming has a proven positive effect on the heat distribution that is initially responsible for hypothermia.
- Warming a patient is easier prior to commencement of a surgical procedure because the patient can be covered completely without interfering with the position or the surgical access.
- Vasodilatation caused by pre-warming makes it easier to insert a peripheral venous catheter.
- Pre-warming has a positive effect on the patient's thermal comfort. Pre-operative active warming is a low-cost, easy-to perform intervention that should at least be applied to patients highly vulnerable to hypothermia complications.

The risk of hypothermia is particularly high at moments when patients are vulnerable, such as before, during and after surgical interventions. Factors that can contribute to hypothermia include the duration of the operation, the location of the wound, the amount of blood loss, the surface area of the wound, the environmental temperature and the anaesthetic technique. Therefore it is not enough to start active warming peri-operatively in order to prevent hypothermia caused by redistribution, because transferring heat requires considerably more time to reach the core thermal compartment.

Furthermore, consideration is given to the fact that even procedures of a short duration entail the possibility of patients becoming hypothermic more readily.

It is therefore asserted that pre-warming (be it active or passive) has proven itself to be a good or even an excellent way of fully preventing hypothermia and its associated complications.

6.1.3 How can the Mistral-Air® Premium Warming Suit be used for pre-warming?

The Mistral-Air® Premium Warming Suit can be used as a normal patient gown or as a forced air warming garment by connecting a Mistral-Air® warming unit to the connector at the lower part of the garment. The heating performance is comparable with that of an Adult / Full Body blanket. During transport, when no warm forced air is applied, the Mistral-Air® Premium Warming Suit functions as a passive insulator. The reflective coating and the multiple layers of fabric have an insulation factor comparable with a duvet.

6.1.4 How does the Mistral-Air® Premium Warming Suit perform in pre-warming?

A multicentre study has been performed with the Premium Warming Suit.

90 ASA I-III patients undergoing surgery of 30-120 min duration under general anaesthesia were randomly assigned to three groups:

A. Standard pre-operative insulation with cotton blankets (30-40 min)
B. Passive pre-operative pre-warming using Premium Warming Suit (30-40 min)
C. Active pre-operative convective pre-warming with Premium Warming Suit (30-40 min)

The conclusion of the multicentre study with the Premium Warming Suit is that active pre-warming with convective air and Premium Warming Suit (Group C) achieves:

- Higher oral temperature before anaesthesia induction
- Significantly higher core temperature, within normothermia range, during anaesthesia, at the end of surgery and also during the post-operative period
- Lower number of patients with intra-operative hypothermia
- No patients with hypothermia at the end of surgery or at PACU arrival

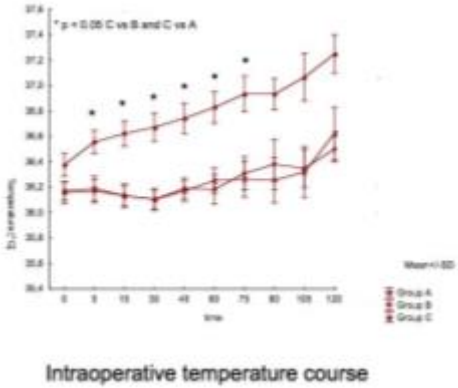


Figure 3 Oesophageal intra-operative temperature (mean +/- SD)

6.2 Passive techniques

- increasing the environmental temperature.
- clothing made of wool and synthetic wool substitutes.
- blankets and undersheets from preheated blanket cupboards.
- insulating materials such as Thermoflect.
- preheated beds.
- filter for ventilation.
- it is also important to keep the entire human body (especially the head) covered; this reduces heat loss by about 30%.

These measures will help to prevent heat loss from becoming too much. Passive techniques are less effective than the active heating techniques, by means of which heat is actively supplied to the human body.

6.3 Active techniques

The three most commonly used active heating techniques are:

- forced air warming by means of a unit that blows warm air into a disposable blanket.
- intravenous fluid warming by means of an inline warming device for all fluids (including blood transfusions) at low, moderate and high flow rates.
- irrigation fluid warming for example during trans urethral resections.

Administration of warm fluids can also best be started pre-operatively, since with these techniques, the greatest benefit can be gained by the prevention of hypothermia. Although it is certainly possible to use one of these three techniques by itself, the greatest effect is obtained by combining them.

6.3.1 Forced air warming

This system consists of a unit that blows warm air through a special disposable blanket that is placed over or under the patient. The warm air escapes through small perforations or a diffusing layer covering the skin of the patient. The blower can be adjusted to different temperatures settings. At present, forced air warming is one of the best ways to combat peri-operative hypothermia. It can be used for both awake and sleeping patients. Forced air warming is an active way that limits the loss of heat by radiation and convection for all patients anaesthetised for longer than 30 minutes.

Advantages:
- Relatively inexpensive.
- The blankets come in various types and sizes.
- The blankets provide warmth to large areas of the human body.
- The unit and the blankets are both user-friendly and patient-friendly.

Disadvantages:
- Rapid active heating is highly dependent on the peripheral circulation.

6.3.2 Blood and fluid warming

Cold fluids are warmed up before being administered to the patient via infusion and/or irrigation. Heated infusion or irrigation fluids can only prevent a further decrease in the core temperature. These techniques have proven their worth in combination with other methods. The warming of blood and blood products must be done with suitable equipment. Warming up blood in unconventional ways (for example in the microwave oven) must be strongly discouraged in order to prevent the blood from being damaged: lysis of the cells and the release of clotting factors actually render the blood unusable.
The problem with most fluid warmers is that the temperature at the end of the patient line is no longer the temperature indicated by the apparatus. An exception to this is the Fluido: this apparatus indicates the temperature that is actually

attained at the end of the line. This is related to the warming technique in the Fluido, i.e. infrared heating, and the way in which the necessary energy is adjusted to the flow (by means of an algorithm).

Advantages:

- Heat loss is prevented.
- Especially convenient and effective in combination with other techniques.
- Useful during irrigation of hysteroscopic, artherosopic surgery, trans urethral resections and peritoneal lavage.

Disadvantages:

- Flow and temperature efficiency ratio
- The time required to start up the apparatus
- The possibilities of adjustment

6.4 Which warming technique is the best?

The clinical effect of conductive and passive warming techniques is small; they merely delay the drop in temperature and primarily affect the comfort of the patient. Passive warming techniques, reflective sheets and cotton blankets are used to reflect the radiant heat or to insulate against a cold environment and thus prevent heat loss. These techniques are in common use, because they are inexpensive and relatively simple to employ. Intravenous infusion or irrigation with fluids at room temperature results in a drop in core temperature. In order to prevent this, blood and fluid warming devices are common use. The capacity of a warming device to maintain or even increase the core temperature depends on the efficiency of the apparatus and the volume of fluid infused. Active warming with forced air is the most efficient way to maintain peri-operative normothermia in both children and adults. It is possible to prevent decreases in core temperature during combined epidural and general anaesthesia. The forced air warming blankets are easy to put in place and are available in a variety of types (upper body, half upper body, lower body, etc.). At present, this warming technique is the most effective.

[7.] Guidelines for temperature management

It is clear that a surgical patient will lose heat. This already begins at an early stage. We must therefore pay attention to a number of factors in order to limit this heat loss. A number of aspects that we can and should take into consideration are already known before the operation:

- the patient's physical condition
- the nature of the intervention
- the duration of the intervention
- the kind of anaesthesia

The warming techniques to be used can already be determined on the basis of this information. There are very few national or international guidelines;

- In 1998, a guideline appeared that was drawn up by the American Society of PeriAnesthesia Nurses (ASPAN). This guideline, the "Clinical Practice Guideline for the prevention of unplanned peri-operative hypothermia", is very useful and quite comprehensive. In the next chapter, the flow charts from this guideline are reproduced to assist you. The complete guideline can be read and printed out via www.aspan.org

- The National Institute for Health and Clinical Excellence (NICE) and the National Collaborating Centre for Nursing and Supportive Care (NCC NSC) have today (23 April, 2008) issued guidance to the NHS in England and Wales on preventing hypothermia in patients before, during and up to 24 hours after surgery (known as perioperative hypothermia).

This guideline was developed by the National Collaborating Centre for Nursing and Supportive Care (NCCNSC) on behalf of the National Institute for Health and Clinical Excellence (NICE, April 2008). The guideline was commissioned and funded by NICE and developed in accordance with NICE processes and methodologies.

NICE clinical guidelines are recommendations about the treatment and care of people with specific diseases and conditions in the NHS in England and Wales.

In this guideline, hypothermia is defined as a patient core temperature of below 36.0°C. Hereafter, ‘temperature’ is used to denote core temperature. Adult surgical patients are at risk of developing hypothermia at any stage of the perioperative pathway. In the guideline, the perioperative pathway is divided into three phases:

the preoperative phase is defined as the 1 hour before induction of anaesthesia (when the patient is prepared for surgery on the ward or in the emergency department), the intraoperative phase is defined as total anaesthesia time, and the postoperative phase is defined as the 24 hours after entry into the recovery area in the theatre suite (which will include transfer to and time spent on the ward). The phrase ‘comfortably warm’ is used in recommendations relating to both the preoperative and postoperative phases, and refers to the expected normal temperature range of adult patients (between 36.5°C and 37.5°C).
http://www.nice.org.uk/nicemedia/live/11962/40396/40396.pdf

NICE guidelines include the following advice:

- Keep patients ‘comfortably warm’ pre-operatively. Use warm blankets and keep the ward environment warm.
- Encourage patients to let staff know if they feel cold at any time, & allow them to walk to theatres.
- Thermometers differ in their reference values. Training in their use is important. Staff must be aware of adjustments made automatically by the devices.
- Anaesthesia should not commence until the patient’s temperature is greater than 36^{O}C.
- A forced air warmer (FAW) should be used after induction for all cases in which anaesthesia is expected to last greater than 30 minutes. It should initially be set to at least 38 ^{O}C
- Patients ASA 2 or higher should all receive FAW from induction
- All administered intravenous fluids should be warmed to at least 37^{O}C
- Irrigation fluid should be warmed to 40^{O}C
- Warming should continue until a temperature of 36.5^{O}C is achieved (intra- and post-operatively)

[8.] Clinical Practice Guideline by the ASPAN

The ASPAN: American Society of PeriAnesthesia Nurses

8.1 Thermal management flow chart

Preoperative Patient Management

Identify patient risk factors for hypothermia.
Measure patient's temperature on admission.
Determine patient's thermal comfort level (ask the patient if he/she is cold).
Observe for signs/symptoms of hypothermia (shivering, piloerection, and or cold extremities).

Patient Normothermic

Institute preventative warming measures:
Passive insulation (apply warm cotton blankets, socks, head covering, and limit skin exposure)
Increase ambient room temperature (minimum 20°-24°C or 68°-75°F)

Patient Hypothermic

Institute active warming measures:
Apply forced air warming system
Apply passive insulation Increase ambient room temperature
(minimum 20°-24°C or 68°-75°F)

8.2 Intra-operative Patient Management

Assessment

Identify patient risk factors for hypothermia
Monitor patient's temperature (see guideline)
Determine patient's thermal comfort level (ask patient if he/she is cold)
Observe for signs/symptoms of hypothermia (shivering, piloerection, and/or cold extremities)

↓

Interventions

Passive insulation (apply warm cotton blankets, socks, head covering, and limit skin exposure)
Increase ambient room temperature (minimum 20°-24°C or 68°-75°F)
Institute active warming measures: apply forced air warming system
Warm fluids: intravenous and irrigants
Humidify and warm gases (anaesthetic)

↓

Expected Outcomes

The patient's core temperature should be maintained at 36°C (96.8°F) or above during the intra-operative phase unless hypothermia is indicated

8.3 Post-operative Patient Management: Phase I PACU

Assessment

Identify patient’s risk factors for hypothermia
Measure patient’s temperature on admission
Determine patient’s thermal comfort level (ask patient if he/she is cold)
Observe for signs/symptoms of hypothermia (shivering, piloerection, and/or cold extremities)

↓ ↓

Patient Normothermic

Institute preventative warming measures:
Passive insulation (apply warm cotton blankets, socks, head covering, and limit skin exposure)
Increase ambient room temperature (minimum 20°-24°C or 68°-75°F)
Measure temperature prior to discharge
Assess thermal comfort level on admission and every 30 minutes (ask patient if he/she is cold)
Observe for signs/symptoms of hypothermia (shivering, piloerection and/or cold extremities)

Patient Hypothermic

Institute active warming measures:
Apply forced air warming system
Passive insulation (apply warm cotton blankets, socks, head covering, and limit skin exposure)
Increase ambient room temperature (minimum 20°-24°C or 68°-75°F)
Warm fluids: intravenous
Humidify and warm gases – oxygen
Monitor temperature every 30 minutes until normothermia is achieved

↓ ↓

Expected Outcomes

Patient’s minimum temperature will be 36°C (96.8°F) prior to discharge from PACU
Patient describes an acceptable level of warmth
Signs/symptoms of hypothermia will be absent

8.4 Post-operative Patient Management: Phase II PACU (ASU)

Assessment

Identify patient’s risk factors for hypothermia
Measure patient’s temperature on admission
Determine patient’s thermal comfort level every 30 minutes (ask patient if he/she is cold)
Observe for signs/symptoms of hypothermia (shivering, piloerection and/or cold extremities)

Patient Normothermic

Institute preventative warming measures:
Passive insulation (apply warm cotton blankets, socks, head covering, and limit skin exposure)

Patient Hypothermic

Institute active warming measures:
Apply forced air warming system
Apply passive insulation
Increase ambient room

Expected Outcomes

Patient’s minimum temperature will be 36°C core prior to discharge from
Phase II PACU (ASU)
Patient describes an acceptable level of warmth
Signs/symptoms of hypothermia will be absent
Patient should describe methods of maintaining normothermia at home.

8.5 *Temperature equivalency chart*

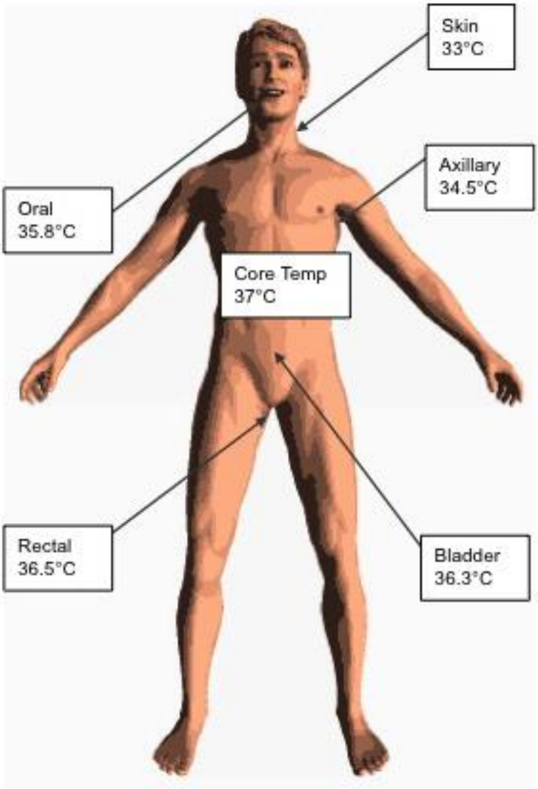


Figure 7: Temperature equivalency chart

Core temperature measurement sites - pulmonary artery, tympanic membrane,* nasopharynx, and oesophagus. **Sites that estimate core temperature** - oral, axillary, skin, bladder and rectum.*

* Rectal temperatures are equal to core temperature when the patient is normothermic. Rectal temperatures become an unreliable measurement when temperature flux is anticipated.
* Accuracy of tympanic temperatures can vary depending on the instrument, operator, and the patient.

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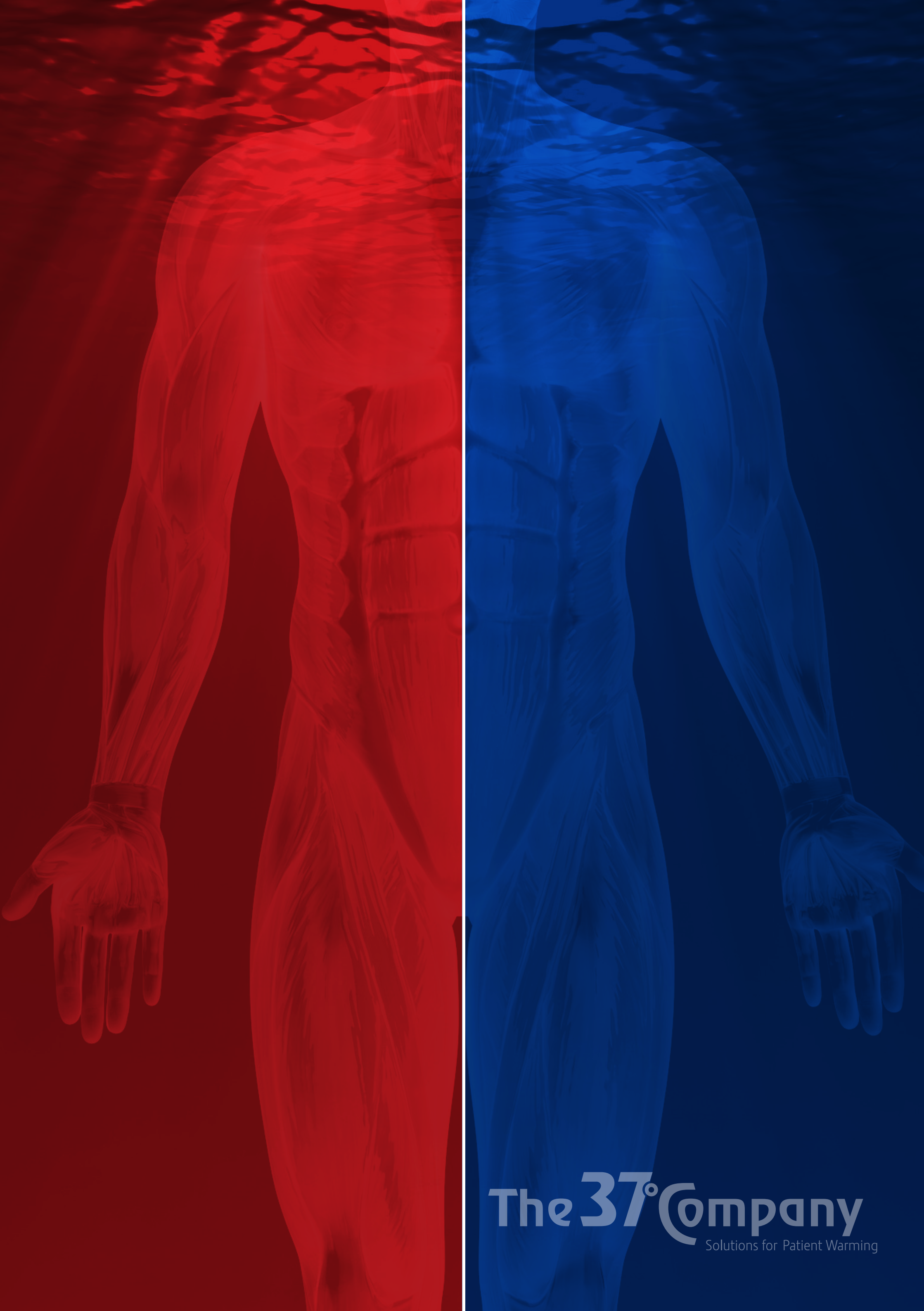
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