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Maintaining Normothermia During Surgery.

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INTRODUCTION

The value of warming in medical practice has been known for thousands of years in treating wounds and for pain relief and, more recently, it has been established that avoidance of hypothermia by systemic warming can reduce blood loss during surgery and post-operative infections[1-5]. It has been recognised that hypothermia in the perioperative period is common, and many other associated complications, can be avoided by using active warming methods. In general there is a considerable morbidity and mortality associated with hypothermia, due to cardiac events and infectious complications in particular[6,7]. Paradoxically, it has to be said that there are situations in which hypothermia is desirable, such as during brain surgery, where targeted hypothermia reduces basal metabolic rate and oxygen consumption, thereby allowing the performance of procedures more safely. However, for the majority of surgical procedures, even minor and intermediate operations, it is important to maintain normothermia.

The reasons why hypothermia should occur during surgery are several and diverse in their nature. Under anaesthesia there is a loss of the behavioural response to cold and impairment of thermoregulatory heat-preserving mechanisms through the hypothalamus and autonomic nervous system. Anaesthetics also cause peripheral vasodilation, causing redistribution of the blood volume with associated heat loss, leading to significant reduction of core temperature. In addition to this, patients may be exposed during their surgery, further accelerating heat loss, and may already have become cold during the inactive period waiting for surgery. With fluid deprivation, conventionally practised for up to 3-4 hours before general anaesthesia, they may also become relatively dry and poorly perfused so that heat distribution by their circulation is further impaired. Finally, although steps may be taken to avoid it, unwarmed anaesthetic gases and intravenous infusions may also add to the reduction of core temperature.

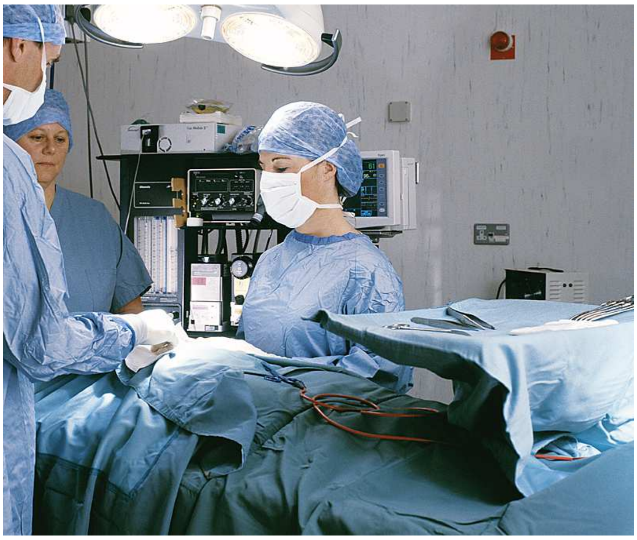
CLINICAL CONSEQUENCES OF HYPOTHERMIA

Hypothermia is clinically accepted to be present when core temperature falls below 36^{o}C. This directly affects the circulatory, immune and coagulation systems. This may contribute to increased blood loss by around 30% and up to a 70% higher probability of need for transfusion during surgery or after trauma[4,5]. The immune system is also affected, and studies have shown that following surgery there is a threefold increase in infective complications in un-warmed patients[2,3]. Hypothermia may be assessed using various techniques, but accurate measurement of core temperature is essential in the perioperative period with early recognition of onset and steps to reverse it.

The clinical effects of hypothermia are easier to grasp. Following the reduction in splancnic and renal blood flow, and consequent reduction in liver and renal excretory or metabolic functions, the effects of many anaesthetic agents are prolonged or made uncertain, notably with opiates and paralysing agents. In severe hypothermia the cardiac output may be reduced by almost a third and thermoregulatory vasoconstriction, which follows such a profound loss of core temperature, may also cause venous stasis. This vasoconstriction can mask hypovolaemia, which may lead to circulatory shock on re-warming and the redistribution of blood volume that follows. Hypothermia may also be associated with an increased de-saturation of venous blood. These cardiovascular responses, when they occur together, increase the risk of myocardial ischaemia, arrythmias, cardiac arrest and potentially the phlebothrombotic complications of deep vein thrombosis and pulmonary embolus[6,8].

BENEFITS OF AVOIDING HYPOTHERMIA

Prevention of hypothermia has a clear benefit for the patient in terms of reduced mortality and morbidity. The advantages for the healthcare provider are equally compelling, with reduced costs and faster patient recovery. A recent review estimated that the annual burden on the European healthcare systems of surgical site infections lies somewhere between €1.5 billion and €19 billion[9]. The infection rates identified involve a wide range but are consistent with previous studies which showed that a reduction of over 65% could be achieved by wider active warming to prevent hypothermia during surgery[7].



Active systemic warming during surgery has significant, proven benefits for the patient and the hospital, yet less than 20% of patients in the UK receive this standard of care.

It has been documented that perioperative hypothermia leads to an increase in the incidence of the following adverse effects: not only wound infections; blood loss; myocardial ischaemia and cardiac disturbances; but also mortality; pain and shivering; and prolonged recovery times. In addition to the implications on outcome for the patient, many of these complications also increase drug usage, bed occupancy (including ward, high dependency and intensive care areas), blood product demand and outpatient attendances. All of these clearly have a direct impact on hospital performance criteria.

By virtue of its effects on tissue perfusion and improved oxygenation, warming has, in addition to the reduction of the risk of surgical site infection, the potential to also reduce delayed healing and infection in traumatic or chronic wounds. There is compelling evidence that both local and systemic warming can achieve this[2,3]. It is possible that ensuring normothermia may act as a substitute, or at least an adjunct, to antibiotic prophylaxis and treatment.

The avoidance of tissue ischaemia by the use of perioperative warming has also been found important in the field of tissue viability. Intra-operative warming during major surgery can reduce the risk of pressure sores by half[10]. Other post-operative complications have also been reduced by ensuring perioperative normothermia. These include less need for blood transfusion[4], because of lower blood loss, and less need for supplementary organ support in high dependency or intensive therapy units. Similarly, post-operative hospitalisation after major elective surgery can be shortened with a reduction in predicted post-operative morbidity and mortality[2,11]. The response to resuscitation where active warming is included, in patients presenting with peritonitis, has also been measurably improved[12].

The benefits to health economics associated with warming are broad, ranging from shorter hospital stays and lower critical care and high dependency bed occupancy to reduced drug usage. Studies have shown that hospital stays can be anything from 20% to 65% longer for patients who become hypothermic during surgery[2,13], with obvious cost and performance implications to the hospital Trust. Longer stay also increases the risk of hospital acquired infection, with the associated costs. The reduction in surgical site infections realised by warming more patients could lower antibiotic use, whilst the lower pain experienced in the post-operative period could decrease the need and demand for analgesia. Lower blood loss results in reduced usage of blood products for transfusion and faster recovery times lessen the utilisation of intensive care and high dependency beds [13, 14].

Reduction of pain in chronic wounds has also been reported with the use of local warming. This is in addition to the mounting evidence of the value of systemic and local warming in arthritic pain, dysmenorrhoea, abdominal pain and renal colic, and minor trauma[15-18]. There is also the same potential in acute wounds with reduction in need for conventional analgesia[19].

There have been reports of the reduction in incidence of the unpleasant complication of shivering in cold patients in the recovery room and during transfers, which carries with it the further risk of increased myocardial work load, oxygen consumption and blood pressure[20, 21]. This indicates the need for managing hypothermic patients, not only during transfer but also in Accident and Emergency units. The potential in air-sea rescue of patients who are lifted from cold exposure in the sea is obvious.

The use of a carbon polymer presents a large, uniform heating area, providing reliable patient warming.

METHODS AVAILABLE FOR WARMING

Heat delivery to prevent or correct hypothermia can be achieved using conduction, convection or radiation. Passive warming can only, at best, conserve heat by insulation, and when used alone is not an effective way of preventing or treating hypothermia in surgical patients. However, active warming techniques may increase heat production by the body or by transfer from an external source, which may be further classified as local or systemic methods.

Active warming has been demonstrated to be effective both in prevention and treatment of hypothermia in the perioperative environment. It has been shown that pre-emptive skin surface warming for 1-2 hours pre-operatively, is effective in reducing the initial redistribution-hypothermia during anaesthesia[22].

Systemic invasive warming methods, such as cavity irrigation and extracorporeal techniques, are used in special circumstances such as cardiac surgery or severe accidental hypothermia. In surgical patients in general, one of the earliest active systemic warming techniques involved the use of circulating water blankets or mattresses, but these are bulky, prone to leaks, and in need of constant maintenance. Electrical warming mattresses using heating elements of various designs have been used for many years, but their performance limitations have restricted uptake for routine clinical practice. Forced air warming was first commercially introduced in the 1980s (Bair-Hugger, Augustine Medical, USA), and this technology has become the gold standard in international healthcare practice. A range of such products are now available and are the most widely and routinely accepted and used worldwide. Recently an innovative new technology has emerged, based around a flexible, conductive carbon polymer (Inditherm Medical Products, UK). Initial indications suggest that this may challenge the position of air warming with the combination of high performance, greater convenience, flexibility and much lower cost offered by carbon polymer mattresses and blankets. The technology could also become a more universally used technique, being adaptable for transport and use in Accident and Emergency. Unlike traditional electrical warming systems, the use of a carbon polymer presents a large, uniform heating area, providing reliable warming, with no reports of burns as there are no electrical elements to break. A comparison of the commonly available warming technologies is shown in Table 1.

Active local warming methods include the application of microwaveable gels, hot wax or water, infrared heaters, disposable exothermic dressings, and conductive carbon polymer pads. Some of these are still under evaluation in the United Kingdom and reports of their use are very encouraging.

CONCLUSION

Maintenance of normothermia in clinical situations improves patient outcomes by enhancing normal physiological responses. The use of systemic warming should now be routine in all classes of surgery unless the special circumstances of hypothermia are indicated. The benefits far outweigh the costs of these techniques, nevertheless experience shows that less than 20% of surgical patients in the UK benefit from active warming during surgery. Cost-effective solutions to the problem are now available, even before the intangible clinical and financial benefits are taken into account. All Trusts involved with secondary care should be addressing this issue.

Table 1. Comparison of Warming Technologies

Technology	Advantages	Disadvantages
Water Mattress	• Ability to cool and heat • Provides pressure relief • No obstruction of surgical field • Does not warm surroundings • Low risk of burning patient	• Water leakage is common • Bulky and heavy • High cleaning requirements • Infection risks • High power consumption • Difficult to handle
Forced Warm Air	• Very fast warm-up time • High warming performance • Little or no capital cost • Low risk of burning patient	• High cost of disposables • Warms surroundings • Needs separate pressure relief • No cooling option • Less patients warmed due to cost and inconvenience
Electrical, using Heating Element	• Silent • Does not warm surroundings • No obstruction of surgical field • No consumables required	• Broken elements can cause patient burns • Poor warming performance • Long warm-up time • Not X-Ray translucent • Needs separate pressure relief • No cooling option
Electrical, using Carbon Polymer Technology	• High warming performance • Fast warm-up time • Low cost, no consumables • Integrated pressure relief • No obstruction of surgical field • Does not warm surroundings • No risk of burns to patient • Can be used on all patients with no extra cost or inconvenience	• No cooling option • Not disposable
Radiant Heater	• Fast warm-up • Good warming performance (if close to patient)	• Bulky • Surrounding area gets hot • Obstructs access to patient • Impractical in operating theatre • Risk of burning patient
Fluid Warmer	• Direct warming of core	• Inadequate warming alone • No effect unless infusing fluid

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