Prevention of hypothermia during orthotopic liver transplantation: comparison of three different intraoperative warming methods

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Summary
Hypothermia is a frequent and sometimes clinically important problem during orthotopic liver transplantation. Numerous methods have been suggested to reduce intraoperative heat loss and promote active warming. In this study we compared an electric under mattress, a warm air under mattress and a forced warm air convective heating blanket. The forced air convective warming system was shown to produce significantly higher patient temperatures than the other two systems. (Br. J. Anaesth. 1995; 74: 415-418)

Key words

Hypothermia is an important and frequent problem during orthotopic liver transplantation [1]. It has also been shown to produce several adverse physiological effects, including abnormalities of blood clotting and platelets [2], electrolyte disturbances and left ventricular dysfunction [3-6]. The patient undergoing orthotopic liver transplantation (OLT) is at particular risk from all of these and is especially vulnerable during the anhepatic phase of operation and during reperfusion when, because of the presence of a donor liver which has been preserved in crushed ice, and the use of veno—venous bypass, the patient's core temperature is at its lowest point during surgery [7].

The use of active warming devices during OLT would therefore be expected to reduce the risks of cardiac arrhythmias and possible arrest during this period and also may reduce the requirement for transfusion of blood and blood products.

Patients and methods
After obtaining Ethics Committee approval and informed consent, we studied 60 adult patients undergoing OLT between May 1992 and August 1993. Patients with fulminant liver disease and those with a history of previous upper abdominal surgery were excluded.

Patients were allocated randomly to one of three groups using a system of sealed envelopes. Group 1 (n = 20) were warmed with an electric under blanket (JMW Medical). This is a full-length silicone rubber pad with implanted electrical heating elements and a series of thermostatically controlled cut-outs set to 39 °C, and with a cut-out at 41 °C. The supply power is 100 W. Group 2 (n = 20) were warmed with a forced warm air under mattress (Howarth). Warm air at 40 °C is blown into the mattress at the head end of the table and escapes through a series of holes in the side. It is set to sound an alarm if the temperature of the air blown in exceeds 41.5 °C. The power consumption is 1100 W. Group 3 (n = 20) were warmed with a forced warm air over blanket (Mallinkrodt). Warm air is blown into the over blanket and escapes through a number of holes on the underside of the blanket to create a warm microclimate surrounding the patient. The temperature is set to high (42-48 °C) which automatically re-sets to medium (36-41.5 °C) after 45 min. Power consumption is 1300 W (heater 1200 W, motor 100 W).

The full-length blanket was modified to facilitate surgery by cutting a hole to expose the abdomen, from the area of the femoral vessels upwards, and the thorax. This was then taped to the patient's skin with waterproof tape (Sleek) in the mid-axillary line. Both legs, one arm (the one not used for veno—venous bypass) and the sides of the abdomen and thorax were therefore covered by the blanket. The head was not covered in any of the groups and no specific measures were taken to reduce heat loss from the head. In addition to this, all patients were kept warm by standard methods. The operating theatre was kept at a constant temperature of 21 ± 1 °C. All fluids administered were warmed to 37 °C with a warmer (Penco Medical) [8] and anaesthetic gases were administered via a circle breathing system with a fresh gas flow of 3 litre min⁻¹.

A standard anaesthetic regimen was used. Patients were premedicated with temazepam, metoclopramide and ranitidine. Anaesthesia was induced with etomidate and fentanyl. After neuromuscular block was produced with atracurium, the trachea was intubated and anaesthesia maintained with 0.5–2% isoflurane, in an oxygen-air mixture. Infusions of dopamine, atracurium and alfentanil were used, together with calcium, noradrenaline and dobutamine as required. After induction of anaesthesia, a
pulmonary artery thermodilution catheter was inserted via the internal jugular or subclavian vein. Pulmonary artery temperature was monitored continuously and recorded at 12 times throughout the operation (table 1).

The results were analysed using one way analysis of variance (ANOVA). Statistical significance was assumed when \( P < 0.001 \).

Results

There were no significant differences between the groups in age, sex, height, weight, blood transfused or duration of surgery (table 2).

The results are shown in table 3 and summarized in figure 1. All patients showed a reduction in core temperature during the pre-anhepatic stage, which usually lasts for 1–3 h. This reduction was less in group 3 and the difference was statistically significant at time 5. This degree of significance was maintained at all subsequent times. All groups showed a further reduction as the donor liver was placed in the body cavity and the core temperature was lowest in all groups at the time of reperfusion (times 7–8).

Patients in group 3 were significantly warmer at this stage and the temperature difference between the groups continued to increase throughout the rest of the operation. Only those in group 3 were normothermic at the end of operation. In fact the lowest temperature in any patient in group 3 at the end of the procedure was 36.4 °C, whereas the highest temperature in either of the two other groups at this stage was 36.0 °C.

There were no complications attributable to any of the warming devices in any patient.

Discussion

Patients undergoing general anaesthesia for all but the briefest of surgical procedures are at risk of developing hypothermia [9, 10]. The abolition of behavioural responses, cold operating theatre, use of cold volatile fluids for skin preparation and loss of heat from the peritoneum during abdominal surgery all contribute. Patients undergoing OLT are at particular risk from these because of the long operating time and large incision. In addition, the need for infusions of large volumes of cold fluid, the use of veno-venous bypass and the additional cooling caused by the cold donor liver exacerbate the problem. The liver is a large producer of heat and patients in liver failure and those in the anhepatic phase of OLT produce less heat in addition to losing more.

A change in core temperature under anaesthesia follows a characteristic pattern [11]. There is an initial rapid decrease caused by anaesthetic-induced peripheral vasodilatation. This increases the mixing between warm core and cold peripheral blood and the core temperature therefore decreases. This is prevented only if the peripheral compartment is warmed to the same temperature as the central before induction of anaesthesia [12]. As this requires the use of a convective warming blanket for 1 h or more before operation it is rarely practical. The environmental factors mentioned above cause increased loss to the atmosphere and this linear decrease in temperature continues until a new equilibrium is reached. This may take several hours.

Methods traditionally used to prevent hypothermia (warm operating theatre temperature, humid-
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fied gases, warmed i.v. fluids) have only limited effectiveness in OLT. There is a limit to the ambient operating theatre temperature which surgeons will tolerate and this is less than the level which ensures normothermia. Heat loss via the respiratory tract is of the order of only 10%. [11] so warming and humidifying gases is only a minor contributor to the prevention of heat loss. Warming i.v. fluids is essential but while this prevents active cooling it does not provide much heat actively to warm the patient. However a recent study has demonstrated that these methods can maintain normothermia during OLT if combined with an efficient warming blanket [13].

Recent studies have demonstrated the effectiveness of the oesophageal rewarming device in maintaining core temperature [14, 15]. This actively warms the core compartment to reduce cardiac hypothermia on reperfusion. The above device does not necessarily prevent postoperative hypothermia as the peripheral compartment is not warmed. Another study suggested that the heat supplied to the central compartment is then distributed peripherally. This latter study did not demonstrate a significant difference in core temperature when patients warmed in this way were compared with controls [16].

Studies have demonstrated the potential effectiveness of forced air convective heating in maintaining normothermia [17-22]. A number of forced air convective warming systems are now available, and it has been demonstrated that there are differences in their performances [23].

Core temperature is usually measured as an approximation to hypothalamic temperature. As hypothalamic temperature cannot be measured directly, various sites have been used to give an approximation [24, 25]. Tympanic membrane temperature is usually thought to give a good estimate, but nasopharyngeal, oesophageal and bladder are acceptable alternatives. The lower third of the oesophagus may be unreliable in OLT as the cold donor liver is placed in close proximity. The pulmonary artery is not usually an easily accessible site, but as a thermodilution catheter is used routinely in these cases it is a convenient site during OLT. During the cooling phase and during large volume blood transfusion, it may underestimate the true hypothalamic temperature as cool peripheral blood reaches the pulmonary artery before it reaches the brain. We excluded patients with previous upper abdominal surgery from the study as they were felt to be more likely to need large volumes of blood. In these circumstances the pulmonary artery temperature may be more an indicator of the efficiency of the blood warmer than of the warming blanket. As the most troublesome effects relate to cardiac support we felt that the pulmonary artery temperature was the most appropriate for our study.

There may be several reasons why the three devices differed in their ability to reduce the reduction in core temperature. The heat energy supplied by the devices was not the same, but in each case the device was used at the settings recommended by the manufacturer. The electric under mattress has the advantage that it does not interfere with the surgical field, and is therefore very convenient. Its disadvantage is that heat is supplied primarily to those parts of the patient in contact with the mattress. These areas have reduced blood flow as they are supporting the patient’s weight and, in addition, the maximum temperature of the device is reduced because of the risk of burns in relatively ischaemic tissue. The warm air under mattress shares the same convenience, but the patient’s weight is distributed more evenly, so increasing the area in contact with the device and available for conduction of heat. Neither device prevents heat loss from the patient’s anterior surface. The warm air over blanket does prevent heat loss from this aspect, so, as little heat is usually lost through the operating table, is more efficient at preventing heat loss. The warm air microclimate produced surrounds the entire patient rather than just the lower aspect. Securing the blanket to the patient with adhesive tape prevents cold fluid reaching the patient’s skin outside the operative field and this may also contribute to reducing heat loss.

In conclusion, patients undergoing OLT are at particular risk of developing hypothermia, especially during reperfusion. This risk may be reduced by actively warming the patient, and the forced air convective warming blanket is the most effective device for doing this.

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References

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