

## ORIGINAL ARTICLE

# Maintenance of normothermia at operation room temperature of 24 °C in adult and pediatric patients undergoing liver transplantation

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## Keywords

adult, anesthesia, general, liver, liver transplantation, monitoring, nasopharyngeal temperature, organ, patient, pediatric, surgery.

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## Summary

Hypothermia is common during surgery in regular operating room (OR) temperature. The effect of increasing the OR temperature to 24 °C coupled with simple warming measures to maintain normothermia in both pediatric and adult patients during living donor liver transplantation (LDLT) was evaluated. One hundred patients undergoing LDLT were separated into pediatric (GI) and adult (GII) groups. Nasopharyngeal temperature (NT) at each hour for the first 6 h, at the time of anhepatic phase, 5 and 30 min after reperfusion, and each hour for the last 2 h of the operation was recorded, compared and analyzed. A significant difference in core temperature variation was noted between the two groups. GI tended to be hyperthermic, while GII remained mildly hypothermic throughout the procedure. A sudden decrease of NT was observed in both groups during the anhepatic and reperfusion phases. Correlation between liver graft weight over recipient body weight ratio rather than the graft weight itself was found in GI, but no such correlation was found in GII. OR temperature of 24 °C, together with simple active and passive warming measures are more effective in maintaining normothermia during liver transplantation in pediatric patients than in adults.

## Introduction

Hypothermia is commonly encountered during anesthesia, characterized by a rapid drop then plateau of core temperature [1]. Adverse physiologic effects including myocardial ischemia [2], coagulopathy [3,4], and immunosuppression [5], resulting in perioperative mortality and morbidity such as fatal cardiac events [2], wound infections [6], and increased blood loss requiring blood transfusion have been documented [7–9]. Thus, it should be a standard practice to keep patients in normothermic during surgery [1,10], especially in the setting of liver transplantation wherein the hypothermia worsens the coagulopathy of end stage liver disease [4,11,12]. Regardless of operative site or anesthetic agent used, adult patients aged 20–85 years have been kept normothermic

by maintaining OR temperature between 24 °C [13] and 26 °C [14]. Likewise, in pediatric living donor liver transplantation (LDLT) setting, keeping the OR temperature at 24 °C together with other active and passive warming measures allows maintenance of normothermia except in the anhepatic and reperfusion phase, a sudden decrease in nasopharyngeal temperature (NT) was observed [15], which was found to be related to the ratio of the cold preserved graft weight over recipient body weight (GRWR) rather than the graft weight itself [15]. No such mechanism has been proposed for adult patients. The aims of this study are to evaluate the impact of cold preserved graft weight and GRWR on the NT during the anhepatic and reperfusion phases of LDLT in adults and, to compare the changes in NT between adult and pediatric patients undergoing LDLT under the same OR condition.

## Patients and methods

The anesthesia records of 100 patients who had undergone LDLT were reviewed. Those aged 18 years and above were categorized as adult, while those less than 10 years of age as pediatric. Adolescent were excluded because their physiological status differs from that of the pediatric and adult patient. All patients were anesthetized in the same OR for LDLT after an informed consent for anesthesia and surgery was obtained. General anesthesia was performed without premedication, and maintained with isoflurane in an oxygen–air mixture. Fentanyl was given whenever necessary and atracurium was used as muscle relaxant. ECG, pulse oximetry, continuous arterial blood pressure, central venous pressure, end tidal CO<sub>2</sub>, urine output, NT (Hewlett Packard Viridia 24C; Hewlett Packard, 71034 Boeblingen, Germany) were monitored continuously. At least four intravenous lines were inserted for replacement of fluids and blood products. The OR temperature was set at 24 °C the night before the operation (Yamatake Honeywell Model SDC 200; Yamatake Honeywell, Tokyo, Japan). A radiant heat lamp was used during induction of anesthesia, and a water blanket (Blanketrol; Cincinnati Sub-Zero Products, Inc, 12011 Mosteller, Cincinnati, OH, USA) with temperature set at 38 °C was used throughout the operation. All four extremities of the patient were wrapped with cotton bandage and covered by stockinet. The anesthetic gases were kept humidified in a filter humidifier (ICOR, Marlborough, Sweden). NT was recorded after induction of anesthesia (obtaining preanesthesia NT in awake and uncooperative children was difficult); hourly for the first 6 h ( $T_1$ – $T_6$ ); at the anhepatic phase ( $T_{anh}$ ) where the lowest NT was noted; 5 and 30 min after reperfusion ( $T_{R5}$ ,  $T_{R30}$ ), and each hour of the last 2 h of the procedure ( $T'$ ,  $T''$ ). Blood loss, blood products and fluid replacement were presented as ml/kg for comparison between adult and children. Mann–Whitney *U*-test was used for comparison of temperature between the two groups. NT changes at the anhepatic and reperfusion phase in the same group was compared using the paired simple *t*-test. Spearman rank-order correlation was applied to analyze the correlation between the decrease in NT seen from  $T_6$  to anhepatic and reperfusion phase, and GRWR or graft weight. Data were given in mean  $\pm$  SD. Statistical calculations were performed using the SPSS advanced statistics module (SPSS Inc, Chicago, IL, USA).  $P < 0.05$  was regarded as significant.

## Results

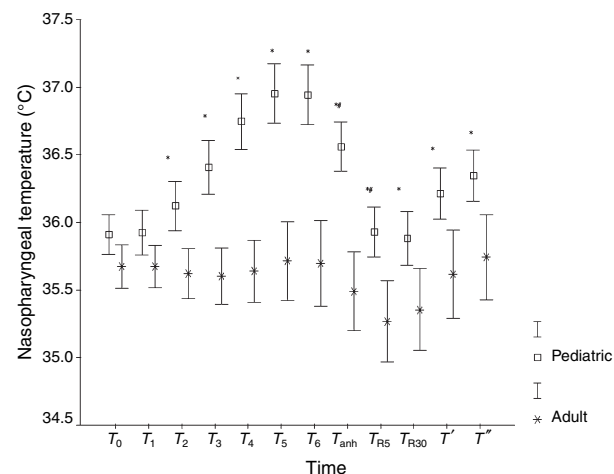
Anesthesia records of 100 patients undergoing LDLT performed from June 1992 to April 2002 were evaluated.

Seventy patients were included in the pediatric (GI) group, 28 in the adult (GII) group and two adolescents (age 13 and 15) were excluded. The demographic and anesthetic variables of the patients, presented in Table 1, revealed significant differences between the two groups in age, height, weight, body surface area (BSA), the ratio of the BSA to body weight, liver graft weight, GRWR; and NT at  $T_6$ ,  $T_{anh}$  and  $T_{R5}$  ( $P < 0.05$ ). There was no difference in blood loss, packed cells transfused, fresh frozen plasma and 5% albumin administered. Children required significantly more crystalloid than adults. NT changes in both groups during the procedure were shown in Fig. 1.

**Table 1.** Patients' characteristics of the pediatric and adult group.

	Pediatric ( $n = 70$ )	Adult ( $n = 28$ )	<i>P</i> -value
Age (year)	2.5 $\pm$ 1.9	45 $\pm$ 10.2	0.000
Weight (kg)	11.1 $\pm$ 4.1	62.3 $\pm$ 9.2	0.000
Height (cm)	83.9 $\pm$ 20.3	164.3 $\pm$ 9.36	0.000
BSA (m <sup>2</sup> )	0.5 $\pm$ 0.1	1.6 $\pm$ 0.1	0.000
Ratio BSA/weight (m <sup>2</sup> /kg)	4.6 $\pm$ 5.5	2.7 $\pm$ 1	0.000
Anesthesia time (h)	13.6 $\pm$ 2.3	14.35 $\pm$ 1.3	0.213
Blood loss (ml/kg)	13.5 $\pm$ 22.7	20.6 $\pm$ 23.9	0.82
Blood transfused (ml/kg)	14.3 $\pm$ 24.6	13.9 $\pm$ 21.7	0.753
FFP (ml/kg)	5.1 $\pm$ 11.5	3.5 $\pm$ 8.7	0.609
5% albumin (ml/kg)	51.1 $\pm$ 54.7	35.3 $\pm$ 19.6	0.316
Crystalloid (ml/kg/h)	11.5 $\pm$ 4.7	8.1 $\pm$ 5.2	0.002
Urine output (ml/kg/h)	3.0 $\pm$ 3.1	2.15 $\pm$ 1.4	0.72
$T_6$ (°C)	36.9 $\pm$ 0.94	35.6 $\pm$ 0.79	0.000
$T_{anh}$ (°C)	36.5 $\pm$ 0.78	35.4 $\pm$ 0.72	0.000
$T_{rep}$ (°C)	35.9 $\pm$ 0.7	35.2 $\pm$ 0.76	0.000
GW (g)	269 $\pm$ 47	704 $\pm$ 100	0.000
GWR (%)	2.65 $\pm$ 0.92	1.14 $\pm$ 0.19	0.000

Values given are mean  $\pm$  SD.



**Figure 1** The nasopharyngeal temperature changes during living donor liver transplantation between two groups. All data were presented in mean  $\pm$  SD. \* $P < 0.05$  between groups, # $P < 0.05$  in the same group for GI and GII.

**Table 2.** Comparison of the sudden drop of the NT from  $T_6$  to NT of anhepatic phase and from  $T_6$  to reperfusion phase between groups.

	GI ( $n = 70$ )	GII ( $n = 28$ )	<i>P</i> -value
$T_6 - T_{\text{anh}}$ ( $^{\circ}\text{C}$ )	$0.4 \pm 0.4$	$0.2 \pm 0.26$	0.064
$T_6 - T_{\text{rep}}$ ( $^{\circ}\text{C}$ )	$1.01 \pm 0.68$	$0.42 \pm 0.30$	0.000

**Table 3.** Spearman rank-order correlation *P*.

	GI ( $n = 70$ )			GII ( $n = 28$ )		
	$T_6$	$T_{\text{anh}}$	$T_{\text{rep}}$	$T_6$	$T_{\text{anh}}$	$T_{\text{rep}}$
<i>P</i> for correlation of GRWR	0.156	0.015	0.001	0.647	0.986	0.425
<i>P</i> for correlation of graft weight	0.444	0.627	0.749	0.573	0.479	0.425

Mild hypothermia with NT  $< 36^{\circ}\text{C}$  was observed during the first 2 h in both groups. A significant difference in NT was noted after 2 h between GI and GII, with the pediatric group exhibiting an increase in NT whereas mild hypothermia persisted in adult group until the end of surgery ( $P < 0.05$ ). Twelve of children had NT over  $38^{\circ}\text{C}$ , so that the OR temperature had to be set down to  $22^{\circ}\text{C}$  and the water blanket shut down. There was a significant drop of NT during the anhepatic and reperfusion phase in both groups but this trend reversed gradually towards the end of the operation with a mean NT of  $36.3 \pm 0.7$  and  $35.7 \pm 0.7^{\circ}\text{C}$  in children and adults, respectively (Fig. 1).

When both groups were compared, decreases in NTs in the reperfusion phase were significantly greater in GI than in GII (Table 2). Decrease in NT correlated with GRWR in GI but not in GII, while graft weight itself did not correlate with NT in either group (Table 3).

## Discussion

Inadvertent hypothermia during anesthesia is by far the most common perioperative thermal disturbance; it results from a combination of impaired thermoregulation and exposure to the cold environment of the operating room [1]. Typical ambient OR temperature set at  $19\text{--}21^{\circ}\text{C}$  for the comfort of the OR personnel causes mild to severe hypothermia in at least 50% of patients, depending on the duration and complexity of the surgery [6,13,14]. Such hypothermia is characterized by an initial rapid decrease in core temperature, due to heat redistribution within the body [16], followed by a slow, linear reduction in core temperature through body heat loss in the cold environment, and finally a relative constant plateau is observed as the heat loss and heat production of the body

reaches an equilibrium [1]. Normothermia has been maintained in patients aged 20–85 years, regardless of surgical procedure or anesthetic agent used, by keeping OR temperature between  $24^{\circ}\text{C}$  [13] and  $26^{\circ}\text{C}$  [14]. In the liver transplantation setting, a different pattern of NT change was observed with the adult and pediatric patients exhibiting significantly different NT despite exposure to identical OR temperature of  $24^{\circ}\text{C}$  and active warming measures. Figure 1 shows that there is a significant difference in the changes of the NTs between groups during the liver transplantation procedure. The mechanism of the different responses between groups is probably because of children having a greater ratio of BSA to body weight (Table 1), allowing faster equilibrium of NT to ambient environment. As a result, children are more prone to hypothermia or hyperthermia [17].

The abrupt drop of NT from  $T_6$  to 5 min after reperfusion ( $T_{\text{R5}}$ ) was  $36.9 \pm 0.9^{\circ}\text{C}$  to  $35.9 \pm 0.7^{\circ}\text{C}$  in the pediatric group and  $35.6 \pm 0.7^{\circ}\text{C}$  to  $35.2 \pm 0.7^{\circ}\text{C}$  in the adult group (Fig. 1). In the anhepatic phase, the donor liver, which has been preserved in  $4^{\circ}\text{C}$  UW solution, is placed in the abdominal cavity. During vascular reconstruction, the graft is flushed with  $4^{\circ}\text{C}$  lactated Ringer's solution (approximately  $1\text{ cm}^3/\text{g}$  liver graft) to wash out the UW solution from the new graft before reperfusion and the venous return through the new graft in reperfusion phase may have contributed to the abrupt change in body temperature [15,18]. The NT gradually returned to  $36.7 \pm 0.7^{\circ}\text{C}$  and  $35.7 \pm 0.7^{\circ}\text{C}$  at the end of the operation in the pediatric and adult groups, respectively, without further intervention. The significantly greater NT change seen in pediatric patients again showed that the greater BSA to weight ratio predisposes their equilibration to the external environment (Fig. 1 and Table 2). Further analysis showed that the degree of decrease in NT in children correlated with GRWR rather than the graft weight [15]. Although adult patients received heavier liver grafts, but the GRWR was significantly smaller when compared with that of the pediatric group (Table 1). In adults neither the GRWR nor the graft weight was the determinant factors for the decrease in the NT seen in the anhepatic and reperfusion phase (Table 3). Other factors, such as anesthesia times, blood loss, blood and colloid replacement, and urine output were not significantly different between the groups, but pediatric patients received a significantly greater amount of crystalloid (Table 1). This may be due to the fact that infants and children require relatively more maintenance of fluids than adults [19].

Maintenance of normothermia in patients undergoing liver transplantation is a challenging task for the anesthesiologist, because end stage liver disease patient usually has associated disease of other vital organs, coupled with intraoperative extensive fluid shifts because of massive

blood transfusion and fluid replacement, often complicate the management of normothermia. Hypothermia can result in coagulopathy even in patients with normal levels of clotting factors and normal prothrombin time or partial-thromboplastin times [11]. Mean prothrombin time increased from  $11.8 \pm 0.3$  s at  $37^\circ\text{C}$  to  $12.9 \pm 0.5$ ,  $14.2 \pm 0.5$  and  $16.6 \pm 0.2$  s at 34, 31 and  $28^\circ\text{C}$ , respectively [3]. Furthermore, direct inhibition of the enzymatic reactions of the coagulation cascades [3,20], and reduced platelet activity as a result of decreased production of thromboxane B [4] exacerbate the cold-induced thrombocytopenia because of bone marrow suppression and hepatosplenic sequestration [21] may result in increased blood loss that subsequently requires further blood transfusion [7–9].

The sudden decrease in NT in the anhepatic and reperfusion phases can be as much as  $1^\circ\text{C}$  in children (Table 2). To prevent severe hypothermia or to maintain normothermia in pediatric patients, we recommend keeping the NT slightly hyperthermic in the dissection phase (Fig. 1). Simple measures such as the radiant heat lamp, water blanket, cotton bandage and stockinet to protect the patients from excessive heat loss, as well as higher OR temperature of  $24^\circ\text{C}$  have allowed us to keep our pediatric patients in normothermia, and adult patients in only mild hypothermia during LDLT. We have found water blanket alone to be inadequate for preventing hypothermia as it provides only a very small area for contact with the body surface [22]. Heat loss by radiation and convection can be further reduced by covering all four extremities with layers of cotton bandages [10]. The wrapped up skin has been found to have a temperature only  $1^\circ\text{C}$  lower than that of the NT [23]. The Bair Hugger convective air warming device has also been proven to protect the legs effectively against cutaneous heat loss [24,25].

## Conclusion

Although noted in both age groups, the sudden decrease in NT during the anhepatic and reperfusion phases has been found to correlate with GRWR only in pediatric patients [15]. Graft weight itself has no apparent correlation with NT in both adult and pediatric patients.

Initially the pediatric patient is mildly hypothermic, then mildly hyperthermic during the pre-anhepatic phase; becoming mildly hypothermia during the anhepatic and reperfusion phases; then normothermia toward the end of the operation. However, the adult patient remains mildly hypothermic throughout the operation despite exhibiting the same drop in NT during the anhepatic and reperfusion phases.

OR temperature of  $24^\circ\text{C}$  aided with the simple active and passive warming measures were effective in

maintaining normothermia during liver transplantation in pediatric patients but less effective in adults.

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