The Effect of Liver Graft–Body Weight Ratio on the Core Temperature of Pediatric Patients During Liver Transplantation

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The left lateral segment of the liver from an adult living donor sometimes is relatively too large for a small pediatric recipient. It currently is unknown whether a high graft-recipient body weight ratio (GRWR) has a significant effect on core temperature during the anhepatic and reperfusion phases of living donor liver transplantation (LDLT). Seventy-two pediatric patients undergoing LDLT were divided into two groups according to body weight. Group I (GI) consisted of patients with a body weight greater than 10 kg, and group II (GII), less than 10 kg. Core temperature, measured as nasopharyngeal temperature (NT), was compared between groups at induction of anesthesia, hourly during the following 6 hours, as the lowest core temperature at the anhepatic phase, 5 and 30 minutes after reperfusion, and the last 2 hours before the end of the operation. Mild hypothermia of 35.8°C ± 0.7°C and 35.9°C ± 0.4°C for GI and GII was noted after induction of anesthesia, respectively; this increased ±1°C in the following 6 hours. In the anhepatic and reperfusion phases, a sudden and significant decrease in NT was observed in both groups. This decrease in NT was significantly greater in GII than GI. In conclusion, a sudden decrease in core temperature was observed during the anhepatic and reperfusion phases of LDLT in pediatric patients, likely caused by placement of the cold liver graft, which is flushed with 4°C lactated Ringer’s solution during vessel reconstruction, in the anhepatic phase and return of venous blood through the cold preserved liver in the reperfusion phase. Core temperatures of pediatric patients with a body weight less than 10 kg in GII, who received grafts with a high GRWR, were more affected than those in GI. (Liver Transpl 2003;9:760-763.)

A shortage of liver donors for low-weight transplant recipients has prompted the development of procedures for liver reduction, split-liver, and living related donor liver transplantation.1–6 Likewise, a shortage of cadaveric donor organs for adult recipients has led to the development of adult-to-adult living donor liver transplantation (LDLT).7,8 A liver graft volume to recipient body weight ratio (GRWR) of at least 0.8 previously9 and currently10 1.0 is required to prevent liver dysfunction after liver transplantation. Therefore, left lateral segmentectomy or lobectomy and right hepatectomy are performed for LDLT in pediatric and adult recipients. However, the left lateral segment graft of an adult liver is often large, causing a high GRWR for infant recipients younger than 1 year or with a body weight less than 10 kg.11 The procured liver graft is usually preserved at 4°C before being implanted in the recipient. The purpose of this study is to compare the effect of GRWR on core temperature changes during LDLT in children with body weights less than and more than 10 kg.

Patients and Methods

One hundred LDLTs were performed from June 1994 to April 2002. Twenty-eight adult LDLTs were excluded from this analysis. The 72 pediatric patients (<18 years) were divided into two groups according to body weight: 40 patients with a body weight greater than 10 kg were included in group I (GI), whereas those with a body weight less than 10 kg were included in group II (GII). Primary diagnoses of patients in GI were biliary atresia (n = 32), glycogen storage disease (n = 5), neonatal hepatitis (n = 2), and Allagille syndrome (n = 1), whereas those of GII were biliary atresia (n = 30) and neonatal hepatitis (n = 2).

All patients were administered the same general anesthesia. Anesthesia was induced by mask with sevoflurane and maintained with isoflurane in an oxygen-air mixture (oxygen fraction, 0.7). Fentanyl was administered when necessary, and atracurium was used as a muscle relaxant. Patients’ vital signs were monitored using electrocardiograph, pulse oximetry, continuous arterial blood pressure and central venous pressure measurements, end-tidal carbon dioxide, urine output, and nasopharyngeal temperature (NT; Hewlett Packard Viridia 24C; Boeblingen, Germany). At least four intravenous catheters were placed for fluid and blood replacement.

The operating room temperature was set at 24°C the night
Effect of GRWR on Core Temperature Changes During LDLT

Table 1. Patient Characteristics

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<thead>
<tr>
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<th>GI (n = 40)</th>
<th>GII (n = 32)</th>
<th>P</th>
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<tr>
<td>Age (mo)</td>
<td>48 ± 35.7</td>
<td>17.1 ± 14.3</td>
<td>.000</td>
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<tr>
<td>Height (cm)</td>
<td>97.3 ± 21.9</td>
<td>70.4 ± 7.7</td>
<td>.000</td>
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<tr>
<td>Weight (kg)</td>
<td>14.7 ± 5.0</td>
<td>7.9 ± 2.0</td>
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<tr>
<td>Anesthesia (hr)</td>
<td>14.2 ± 2.7</td>
<td>12.9 ± 1.56</td>
<td>.25</td>
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<tr>
<td>Graft weight (g)</td>
<td>294.7 ± 78.9</td>
<td>254.9 ± 48.4</td>
<td>.009</td>
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<tr>
<td>GRWR</td>
<td>2.1 ± 0.5</td>
<td>3.3 ± 0.86</td>
<td>.000</td>
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<td>Cold ischemic time (min)</td>
<td>74. ± 34.2</td>
<td>61.1 ± 20.3</td>
<td>.247</td>
</tr>
<tr>
<td>Warm ischemic time (min)</td>
<td>45.6 ± 7.8</td>
<td>43.5 ± 4.6</td>
<td>.566</td>
</tr>
<tr>
<td>Anhepatic time (min)</td>
<td>71.2 ± 38.0</td>
<td>64.8 ± 11.8</td>
<td>.793</td>
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</table>

Before surgery (Yamatake Honeywell model SDC 200; Tokyo, Japan). To minimize heat loss, we used a radiant heat lamp during induction of anesthesia and a heating blanket with the temperature set at 38°C during surgery. Moreover, the patient’s four extremities were wrapped with cotton bandages, then covered by stockinet. A filter humidifier (ICOR, Malborough, Sweden) was used to maintain the humidity of anesthetic gases.

Procurement of the liver graft was determined by the surgeons according to preoperative radiological evaluation.12,13 After procuring the liver graft from the donor, the graft was flushed through a cannula in the portal vein with 4°C lactated Ringer’s solution, then flushed and preserved in 4°C University of Wisconsin (UW) solution. The weight of the graft obtained before implantation and recipient body weight were used to calculate GRWR. To allow comparison and analysis of core temperatures between the two groups, NT was recorded at the following times: after induction of anesthesia, hourly during the first 6 hours after induction, the lowest NT during the anhepatic phase, and 30 minutes after reperfusion, and during the last 2 hours of the operation.

Statistical Analysis

Measurements between groups were compared using Kruskall-Wallis test. NT changes from temperature at hour 6 (T6) to the anhepatic and reperfusion phases in the same group were compared using paired simple t-test. All data are given as mean ± SD. Statistical calculations were performed using the SPSS advanced statistics module (SPSS Inc, Chicago, IL). P less than .05 is considered significant.

Spearman rank-order correlation also was applied to analyze the correlation between decrease in NT from T6 to the anhepatic and reperfusion phases and GRWR or graft weight.

Results

From June 1994 to April 2002, a total of 72 LDLTs were performed in pediatric patients. GI consisted of 40 patients with a body weight greater than 10 kg. Types of grafts for patients in GI were 12 left-lateral segments (segments 2 plus 3), 24 extended left-lateral segments (segments 2 plus 3 plus partial 4), 3 left lobes (segments 2 plus 3 plus 4, including the middle hepatic vein), and 1 right lobe. GII consisted of 32 patients with a body weight less than 10 kg. Types of grafts for patients in GII were 29 left-lateral segments (segments 2 plus 3) and 3 extended left-lateral segments (segments 2 plus 3 plus partial 4). Age, height, recipient weight, and liver graft weight were significantly greater in GI, whereas GRWR was significantly greater in GII (Table 1). Other factors, such as anesthesia time, cold and warm ischemia times of the graft, and anhepatic time were not different between the groups.

Changes in NT during the surgical procedure in both groups are shown in Figure 1. After induction of anesthesia, mild hypothermia was present in both groups, with NTs of 35.8°C ± 0.7°C and 35.9°C ± 0.4°C, respectively. NTs were 35.8°C ± 0.7°C, 36.3°C ± 0.7°C, 36.7°C ± 0.7°C, 37°C ± 0.7°C, and 37°C ± 0.7°C for GI and 35.9°C ± 0.4°C, 36.4°C ± 0.9°C, 36.4°C ± 0.9°C, 36.8°C ± 1.1°C, and 36.8°C ± 1.1°C in the following 6 hours for GII. Changes in NTs in the dissection phase between the groups were not significant. However, during the anhepatic and reperfusion phases, both groups experienced a significant decrease in core temperature, from 37°C ± 0.7°C to 36.7°C ± 0.5°C and 36.1°C ± 0.6°C in GI and from 36.8°C ± 1.1°C to 36.3°C ± 0.9°C and 35.6°C ± 0.9°C in GII, respectively.

![Figure 1. Changes in nasopharyngeal temperature (NT) in both groups during the liver transplantation procedure. *P < .05 between groups. +P < .05 in the same group. Op. end = End of operation.](image-url)
When both groups were compared, decreases in NTs in the anhepatic and reperfusion phases were significantly greater in GII than GI. Decrease in NT correlated with GRWR, but not the graft weight itself (Tables 1 and 2; Fig. 2).

**Discussion**

During the dissection phase, core temperatures increased slightly in both groups, but decreased significantly during the anhepatic and reperfusion phases. It is known that in non–liver transplantation surgical procedures, normothermia usually can be maintained with an operating room temperature of 24°C to 26°C regardless of type and length of anesthesia or surgery. Therefore, the sudden decrease in NT in the anhepatic phase and especially the reperfusion phase must be inherent to the liver transplantation procedure.

In the anhepatic phase, the donor liver, which has been preserved in 4°C UW solution, is placed in the abdominal cavity. During vascular reconstruction, the graft is flushed with 4°C lactated Ringer’s solution to wash the UW solution from the new graft before reperfusion. The amount of 4°C lactated Ringer’s solution used in our practice is approximately 1 mL/g of liver tissue. The cold donor liver and cold lactated Ringer’s flush solution caused a significant decrease in core temperature in both groups during the anhepatic phase (Fig. 1), followed by an additional decrease at reperfusion. Moreover, changes in NT were more significant in GII than GI. The additional decrease in core temperature most likely is caused by the return of venous blood to the heart after passing through the cold donor liver.

Although in LDLT, a GRWR of 0.8 to 1 usually is enough for the recipient, the problem of too-small and too-large GRWR can be encountered in adults as well as in small infants. Because the smallest functional unit of a graft should include the hepatic artery, portal vein, hepatic vein, and bile duct, a left-lateral liver graft should consist of at least segments 2 and 3. Although small, it may still be large for a small infant, which may affect core temperature. Our results show that core temperature in patients with a body weight

![Figure 2. Scatter plot of nasopharyngeal temperature (NT) changes versus Graft-recipient body weight ratio (GRWR) in the anhepatic and reperfusion phases.](image-url)

<table>
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<th>Table 2. Spearman Rank-Order Correlation P</th>
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<td>T6</td>
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<tr>
<td>P for correlation of GRWR</td>
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<td>P for correlation of graft weight</td>
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NOTE. Decrease in NT in the anhepatic and reperfusion phases correlated with GRWR, but not graft weight. Abbreviations: T6, six hours after start of operation.
less than 10 kg, and therefore often receiving a liver graft with a greater GRWR, decreased more than in larger recipients. Efforts to maintain normothermia or slight hyperthermia in the dissection phase are necessary to prevent severe hypothermia with subsequent complications in the anhepatic and reperfusion phases.

In conclusion, a sudden decrease in core temperature was observed in the anhepatic and reperfusion phases during LDLT in pediatric patients. This phenomenon is related to placement of a cold liver graft, flushing of the graft with 4°C lactated Ringer’s solution, and return of venous blood after passing through the cold preserved liver in the reperfusion phase. Pediatric patients with a body weight less than 10 kg receiving a graft with a greater GRWR had their core temperatures affected more than larger pediatric patients.

References