Blood-Transfusion Requirements and Blood Salvage in Donors Undergoing Right Hepatectomy for Living Related Liver Transplantation

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Living related liver donation for liver transplantation in adults including its risks is receiving increased attention. We present data from 44 liver donors focusing on transfusion requirements and avoidance of heterologous transfusion. The volume of blood transfused (both autologous from preoperative donation and heterologous) was assessed including that derived from intraoperative isovolemic hemodilution, cell-saver salvaged, and retransfused blood. Hemoglobin concentration and central venous pressure were measured at specified time points before and during surgery. Intraoperative blood loss was calculated and correlated to the duration of parenchymal transsection, liver volume resected, and central venous pressure. There were no specific anesthesia-evoked complications. In 4 donors, major bleeding (>2000 mL) occurred. Blood loss averaged 902 ± 564 mL (SD), yielding a minimal mean hemoglobin concentration of 8.1 ± 1.2 g/dL. One donor received 3 U of heterologous blood and 30 donors received autologous blood from their preoperative donation. An average of 592 ± 112 mL of blood derived from perioperative acute isovolemic hemodilution was retransfused as was 421 ± 333 mL of washed red cells from the cell-saving system. Avoidance of heterologous blood transfusion, application of blood-saving techniques, and efficient pain management are crucial for adult living liver donors. Transfusion of banked blood can be avoided in most patients when intraoperative cell salvage, preoperative autologous blood donation, and intraoperative hemodilution are combined.

(Anesth Analg 2003;96:351–5)

Because living donor liver transplantation (LDLT) in children has become an established procedure (1–3), a number of LDLTs have been performed in adults (4–8). Because of increased acceptance of organ donation, elective timing of transplantation, and decreased ischemic time of the graft, a growing number of LDLTs in adults can be expected.

Because the left liver lobe does not provide sufficient tissue to sustain most adult liver recipients, a right hepatectomy (4,9) is performed for LDLT in adult donors. However, there is considerable debate concerning the ethical aspect of imposing the risk of such major surgery (i.e., a right hepatectomy) and anesthesia on healthy individuals "only" for the sake of the recipient (10,11).

Accordingly, in addition to a thorough evaluation of potential donors and refined surgical techniques, anesthetic perioperative management is crucial for minimizing risks. An extended surgical procedure such as a right hepatectomy has major implications for hemodynamics, hemostasis, blood loss (including different techniques to minimize net red cell loss), fluid and electrolyte balance, and pain management. Thus, the anesthesiologist assumes responsibility not only for anesthesia but also for the process of donor evaluation.

Surprisingly, the perioperative anesthetic management for adult donor right hepatectomy for LDLT has not been addressed until recently and in only eight patients (12). We report our experience with blood-transfusion management for living liver donors focusing on perioperative blood-saving techniques such as predonation and autologous blood

Accepted for publication September 30, 2002.
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DOI: 10.1213/01.ANE.0000041595.94354.48

0003-2999/03

ANESTH ANALG 2003;96:351–5

transfusion, isovolemic hemodilution, and cell salvage (13,14).

Materials and Methods

Data are presented from 44 donors (Table 1) in whom a right hepatectomy (segments 5–8) was performed for adult LDLT during the period of April 1998 to January 2001. After permission from our institutional review board was granted, we obtained data from the patients' anesthesia records and a donor database.

The surgical technique consisted of a right hepatectomy (segment 5–8). Parenchymal transsection was performed across the cantilie line without vascular occlusion and the right hepatic vein remained on the donor side. Except for one patient (young otherwise healthy woman with a history of smoking and oral contraceptive drug intake), we only accepted donors with not more than a single (cardiac) risk factor (i.e., marked obesity with a body mass index >30 (n = 3), smoking history (n = 2), arterial hypertension (n = 1), aortic valve stenosis grade II (n = 1), or mitral valve insufficiency II° (n = 1), and mitral valve prolapse (n = 1).

Besides standard care, we offered preoperative blood donation, intraoperative isovolemic hemodilution (starting with the ninth donor), use of a cell saver, and insertion of an epidural catheter for perioperative pain therapy. Acute isovolemic hemodilution (AIH) was performed via a large bore venous access (usually the external jugular vein) and normovolemia was maintained with hetastarch (Haes-steril® 10%, MW 200,000; Fresenius Kabi, Bad Homburg, Germany) keeping the central venous pressure (CVP) unchanged. A volume of 400–500 mL of blood was strived for during AIH. Autologous blood units sampled preoperatively were separated into 1 U of packed red cells and 1 U of fresh frozen plasma.

All patients received anesthesia with isoflurane and IV boluses of fentanyl, as required. In most of the donors, a thoracic epidural catheter was inserted preoperatively between the T 6/7 and T 10/11 interspace (except in those who refused insertion or when communication with donors was hampered by language problems). We inserted a radial arterial line, a central venous catheter, and at least two large bore peripheral venous lines. During surgery, the patients received epidurally bupivacaine 0.5% for suppression of noxious stimulation and bupivacaine 0.25% with or without epidural morphine for analgesia after surgery.

Hemoglobin concentration and CVP (electromanometry, transducers referenced to the midaxillary line) were measured at defined points in time (start of surgery, after AIH, before and hourly after hepatic resection). The volume of blood withdrawn (and retransfused, respectively) during predonation or isovolemic hemodilution was assessed. In cases in which heterologous blood or plasma had to be transfused, the respective volume was recorded. Because an autologous blood recovery system (Cell Saver® 5; Hemonetics Corp., Braintree, MA) was used in all patients, the volume of salvaged blood and the volume of washed retransfused red cells were also recorded. Surgical blood loss was calculated as the sum of blood collected in the cell saver, in other suction systems, and that estimated to be contained in cotton swabs and compresses minus the recorded volume of fluid used to flush the surgical site and the cell-saver collection system.

Table 1. Characteristics of Donors (n = 44) Undergoing Right Hepatectomy for Living Donor Liver Transplantation

	Mean ± SD	Range
Age (yr)	36 ± 8.5	20–55
Weight (kg)	73 ± 14.1	50–117
Height (cm)	173 ± 8	161–193
Sex (male/female)	23/21	

Weight of the resected graft was measured by using a scale after hemihepatectomy and the fraction of resected liver tissue over total liver volume was estimated from preoperative magnetic resonance imaging studies.

We also investigated any correlations between estimated blood loss and resected liver volume, duration of surgery, duration required for parenchymal transsection, and both mean CVP during surgery and the difference between baseline CVP after the induction of general anesthesia and mean CVP during surgery. Finally, data from the first 22 and the subsequent 22 donors were compared with regard to blood loss.

Data were expressed as mean ± SD. Means of variables from the first 22 and the subsequent 22 donors were compared with a Student's t-test for unpaired data after assurance of normal distribution. For assessment of correlations, a bivariate correlation using the Pearson correlation was performed. A P value < 0.05 was considered statistically significant.

Results

Of 44 donors investigated, major bleeding occurred in 4 patients (>2000 mL of estimated blood loss and a maximal blood loss of 2600 mL in 1 patient). Right hepatectomy provided grafts of 877 ± 146 (range, 600–1150) g. The fraction of resected liver tissue averaged 54% ± 10%. The duration of surgery (skin incision to closure) was 327 ± 61 min.

Forty-two of 44 donors donated blood with an average of 1104 ± 384 mL obtained within the last 3–4 wk before surgery. Hemoglobin concentration averaged 11.8 ± 1.4 g/dL at the start of surgery, decreased to 9.6 ± 1.2 g/dL after AIH, and reached a nadir of 8.1 ± 1.2 g/dL during surgery. The respective calculated hematocrit values were 34.5% ± 4.0%, 28.0% ± 3.7%, and 23.5% ± 3.5%.

Overall, 31 patients (70%) had blood loss (Fig. 1) requiring transfusion, i.e., 30 with autologous red packed cells and/or autologous fresh frozen plasma from predonation before surgery, and with both heterologous and autologous blood in only a single patient (Fig. 2). An average of 1.9 ± 0.8 U of autologous packed red cells and 2 ± 0.8 U of autologous fresh frozen plasma were retransfused in these patients. One donor received 3 heterologous units of packed red cells each containing approximately 350 mL. Thirteen donors did not require any blood products.

Estimated intraoperative blood loss averaged 902 ± 564 (range, 150–2600) mL with 4 donors losing blood in excess of 2000 mL. Distribution of blood loss in all 44 donors is shown in Figure 1. However, comparing the first 22 and subsequent 22 donors, there was a slight but significant ($P = 0.038$) decrease in blood loss (983 ± 656 versus 820 ± 472 mL). Three major blood-loss events occurred in the first 22 and 1 in the subsequent 22 donors. After the initial 8 patients, AIH with colloids (hetastarch 10% [HES 200/0.5]) was performed routinely in all donors except 1 who had a hemoglobin concentration of 9.8 g/dL after the induction of general anesthesia. An average of 592 ± 112 mL of blood was withdrawn during hemodilution. Of those 8 donors that were not hemodiluted, only 1 had a blood loss of >2000 mL.

Blood, 2436 ± 998 mL, and heparinized solution were collected by the cell-saver system and 421 ± 333 (range, 70–1995) mL of washed red cells were retransfused (Fig. 2).

Blood loss did not correlate with volume of liver tissue resected ($r = 0.42$) or with mean CVP at any time during surgery ($r = 0.29$), or with the difference between average (8.1 ± 2.8 mm Hg) and baseline CVP (7.5 ± 3.1 mm Hg) ($r = 0.17$).

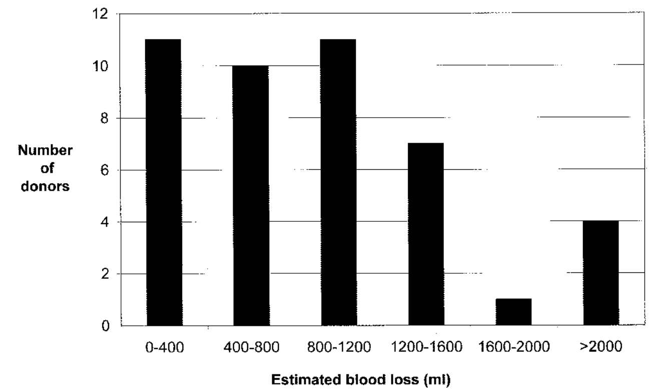

Figure 1. Estimated blood loss (mL).

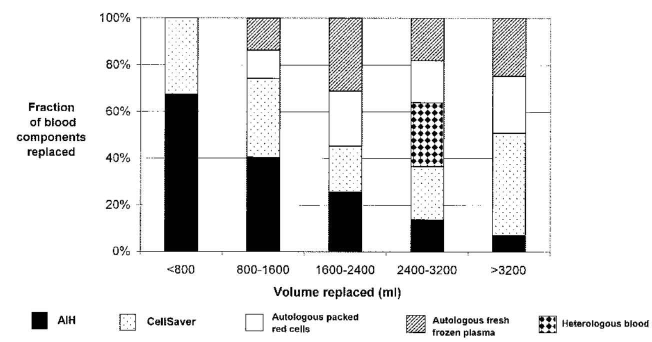

Figure 2. Blood component replacement in living donor liver transplantation donors.

Discussion

Anesthesia-related aspects covering the experience with 44 adult living liver donors undergoing right-sided hemihepatectomy are reported. Because major blood loss is a vital concern and transfusion requirements correlate significantly with morbidity and mortality after liver surgery (15), emphasis was placed on blood-saving techniques.

Until now, experience has only been accumulated in pediatric LDLT (1,2,16–18), where a left lateral liver lobe is donated by an adult. Because liver donation is performed with increasing frequency for adult recipients, measures to minimize undue pain and discomfort, blood loss, and heterologous blood transfusions, and to maximize safety of the healthy donors are important issues for both patients and LDLT programs. In this study, we concentrated on blood-saving techniques for this group of patients. The most important finding is that, with the application of all state-of-the-art blood-saving techniques, living liver donation surgery in adults is possible without transfusion of heterogenous blood in most cases.

There were no anesthesia-related complications in the donors studied. However, 70% of the donors required a blood transfusion, and major bleeding exceeding 2000 mL occurred in 4, 1 of them requiring 3 units of heterologous blood. In these donors, most of the blood loss occurred during parenchymal transsection secondary to anatomical abnormalities of liver vasculature or complicated surgery.

According to German guidelines on therapy with blood and blood products (19), autologous blood donation should be offered to all patients scheduled for surgery with a 10% or more probability for blood transfusion. Except for rare donors presenting contraindications to autologous blood donation (the only contraindication in our donors was refusal to donate), our data suggest donation of 3 units (each approximately 480 mL) of autologous blood for donor right hepatectomy. This seems to be a reasonable number allowing a margin of safety because an average of 1.9 (±0.8) units of autologous packed red cells and 2 (±0.8) units of fresh frozen plasma were retransfused. In fact, the potential need for transfusions later in the postoperative course was not addressed in this study.

Furthermore, 3 of the 4 donors with blood loss exceeding 2000 mL had 3 units of autologous blood transfused, yielding a minimal hemoglobin of 7.2 g/dL (in the above-mentioned 4 patients). Thus, three units of blood donated preoperatively also provided sufficient autologous blood for later retransfusion. In fact, the single patient who required heterologous blood transfusion had declined to donate more than a single unit of autologous blood. Having donated three units supposedly would have saved him from receiving heterologous blood.

Estimation of blood loss remains controversial. No common guidelines exist, and many authors do not comment on how exactly blood loss was estimated in their respective studies. For a right hepatectomy in living donors, there are few reports mentioning blood loss. Marcos et al. (6) reported a mean blood loss of 615 mL in the first 20 donors and 699 mL in the subsequent 20 donors. A median blood loss of 719 (range, 200–1600) mL was reported by Fan et al. (20) who obtained extended right lobe grafts. Estimated blood loss averaged 902 (±564) mL in our donors, yielding a significant decrease in mean hemoglobin concentration from 11.8 g/dL to a minimum of 8.1 g/dL.

Blood-saving techniques were applied from the beginning except for AIH with hetastarch, which started after eight donors. Of note, we found a significant decrease in blood loss as more LDLTs were performed. This suggests that blood loss can be decreased with refined surgical techniques and/or growing experience. In contrast, we could not find correlations between estimated blood loss and duration of surgery or time required for liver transsection, or graft weight. Furthermore, neither CVP nor the difference between average CVP during hepatic transsection and baseline CVP after catheter insertion correlated significantly with blood loss. Possible interdependence of CVP and blood loss in liver surgery has been discussed before. Whereas some authors (21,22) reported a significant correlation between blood loss during parenchymal transsection and CVP, others have failed to find a correlation (23). However, several issues complicate an assessment, such as tilt of the operating table during hepatic transsection changing CVP measurements, positive end-expiratory pressure, intrathoracic pressure, use of surgical retractors, and liver manipulation. In addition, in our patients, right hepatectomy was performed in normal livers and at normal CVPs as opposed to other patient populations (21,22). Supporting our results, no significant correlation between CVP and blood loss was found in donors undergoing left lateral hepatectomy in LDLT for children. Thus, although maintaining a reasonably low CVP during parenchymal transsection may be desirable, apparently it is not a crucial factor in determining blood loss in otherwise healthy liver donors.

During AIH we accepted dilutional anemia to a hemoglobin concentration of 9.6 ± 1.2 mg/dL (after AIH) and a further decrease in hemoglobin concentration to 8.1 ± 1.2 mg/dL (minimal hemoglobin) during surgery with a minimal hemoglobin concentration between 8.0–8.3 mg/dL being an indicator for transfusion. The initial hemoglobin concentration (11.8 ± 1.4 mg/dL) in our patients was rather small. Therefore, we only removed an average of 592 ± 112 mL of blood. According to studies (24,25), the decreased hemoglobin concentration during AIH is well compensated for by sympathetic activation, a compensatory increase in cardiac output, and decreased viscosity. Accordingly, with a hemoglobin concentration of 8.0–8.3 mg/dL, no decrease in systemic oxygen delivery below values before AIH is to be expected in healthy donors. Strictly speaking, we cannot determine whether AIH helped to save blood independent of growing surgical experience. However, 8 of 9 patients that were not hemodiluted received autologous blood, whereas 12 of 35 patients that had blood from AIH retransfused did not receive autologous blood. According to the literature, AIH seems to be beneficial and safe in major hepatic resection (26).

According to proposed criteria (27), an expected blood loss of 1000 mL justifies the use of a cell-saver system which was used in all donor operations. Dilutional coagulopathy described as one of the possible complications (27) should not be expected with an average retransfused red cell volume of 421 ± 333 mL. Therefore, intraoperative cell salvage should be applied in all donor operations for LDLT. The return rate of 421 ± 333 mL seems large in comparison to an average calculated blood loss of 902 ± 564 mL. However, in some cases, the collected blood from the surgical field was diluted by the washing solution and fluids used to flush the surgical field even yielding a very large return rate of 1995 mL in 1 patient.

In conclusion, assurance of safety for the donor undergoing right hemihepatectomy in LDLT is crucial. Avoidance of heterologous blood transfusion and combined application of all blood-saving techniques are important. With the application of intraoperative cell salvage, three preoperative autologous blood donations, and AIH right hepatectomy for the donor operation in adult LDLT is possible without heterologous blood transfusions in most patients.

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