ORIGINAL ARTICLE

Safety of Donors in Live Donor Liver Transplantation Using Right Lobe Grafts

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Hypothesis: Right lobe donation was advocated for adult-to-adult live donor liver transplantation but the safety of the donor is still a major concern. We hypothesize that right lobe donation is safe if the lowest limit of volume of liver remnant that can support donor survival is known.

Design: Retrospective analysis of data collected prospectively.

Setting: Tertiary hepatobiliary surgery referral center.

Patients: Twenty-two live donors involved in adult-to-adult right lobe liver transplantation from May 1996 to June 1999.

Interventions: The right lobe grafts were obtained by transecting the liver on the left side of the middle hepatic vein. Liver transection was performed by using an ultrasonic dissector, without using the Pringle maneuver. The left lobe volume was measured by computed tomographic volumetry and the ratio of left lobe volume to the total liver volume was calculated.

Main Outcome Measures: Hospital mortality rate and complication rate.

Results: The median blood loss was 719 mL (range, 200-1600 mL). Only one donor, who had thalassemia, received 1 U of homologous blood transfusion. Postoperative complications included wound infection, incision hernia, and cholestasis in 1 donor whose liver showed 20% fatty change and who had a left lobe–total liver volume of 0.34. Another donor with 15% fatty change in the liver and a left lobe–total liver volume ratio of 0.27 developed prolonged cholestasis. Two other donors with left lobe–total liver volume ratios of 0.27 but with mild steatosis (<5%) did not develop postoperative cholestasis. Postoperative complications also included 1 case of biliary stricture and 1 case of small bowel obstruction. Both complications were adequately treated. There was no donor mortality. All donors are well and have returned to their previous occupations.

Conclusion: Live donation of right lobe graft for adult-to-adult liver transplantation is safe provided that the residual liver volume exceeds 30% of the total liver volume and the liver itself is normal or only mildly affected by steatosis.

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LIVE DONOR liver transplantation using extended right lobe graft was advocated to treat adult patients who could not receive a timely cadaveric graft.[1] Since donation hepatectomy is complicated, lengthy, and involves resection of 60% to 70% of the total volume of the donor's liver, the safety of the donor is the major concern. In this report, we analyzed the data of the donors of our first 22 live donor liver transplantations using right lobe grafts to determine the criteria of selection of donors so that potential donors who are at risk of liver failure would not be subject to donor hepatectomy.

RESULTS

Intraoperatively, mishap occurred to donor 2. At the time of harvesting, the vascular clamp applied to the junction of the middle and left hepatic vein during the harvesting procedure accidentally occluded the left hepatic vein and resulted in congestion of the liver remnant. The mistake was recognized only after division of the middle hepatic vein and was rectified after suturing of the middle hepatic vein orifice. For the other donors, the operations were uneventful.

The duration of the donor operation was 8.3 to 15.5 hours (median, 11.8 hours). The median blood loss of the operation (including blood loss from the graft during harvesting) was 719 mL (range, 200-1600 mL) (**Table**). The first and second donors received 500 mL of autologous blood. For the other donors, only donor 13, who had thalassemia, received 1 U of homologous blood. At the time of blood transfusion, her hemoglobin level was 69 g/L. Blood collected in the cell saver

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PATIENTS AND METHODS

From May 1996 to June 1999, 22 live donor liver transplantations using right lobe grafts were performed at Queen Mary Hospital, Hong Kong. The ages of the donors ranged from 18 to 51 years (median, 35.5 years). They were fathers (n = 2), spouses (n = 8), daughters (n = 3), son (n = 1), brothers (n = 3), sister (n = 1), aunt (n = 1), uncle (n = 1), nephew (n = 1), and brother-in-law (n = 1) of the recipients. All donors received psychological counseling before the donor operations. They were screened by laboratory tests including complete blood cell count, liver and renal biochemistry values, and viral serologic studies. The blood types of all donors were matched or compatible with the recipients. Autologous blood collection was made in the first 2 donors but not in the subsequent donors. Computed tomography (CT), CT volumetry, and hepatic arteriography were routinely performed. The hepatic vein anatomy was carefully studied on the CT scan, particularly in the region of middle hepatic vein (**Figure 1**).

The donors were prepared on the operating table with care to avoid sores at the pressure points. Heparin was given subcutaneously in 2 female donors who had a history of taking oral contraceptive pills. In 3 donors (2 with slightly abnormal liver biochemistry results [alanine aminotransferase level greater than the upper limit of normal] and 1 with a CT scan finding of splenomegaly), laparoscopy and liver biopsy were performed before laparotomy.

The laparotomy was performed via bilateral subcostal incision with an upward midline extension. Intraoperative ultrasonography was performed to identify the presence of a large right inferior hepatic vein (accessory right hepatic vein) and to study the junction of the middle hepatic vein with the inferior vena cava. Operative cholangiography via cystic duct cannulation was performed to study the bile duct anatomy. Hilar dissection was then performed to isolate the right hepatic artery and right portal vein. All portal vein branches to the caudate process were divided and ligated. The right lobe of the liver was then rotated toward the left side for division of right triangular ligament and tiny venous branches between the anterior surface of the inferior vena cava and posterior surface of paracaval portion of the caudate lobe. The rotation was intermittent to avoid prolonged twisting of the inflow and outflow vascular pedicles of the left lobe. The right hepatic vein and the right inferior hepatic vein larger than 5 mm were preserved until the time of harvesting.

The liver was transected at a plane on the left of the middle hepatic vein by using an ultrasonic dissector. The transection plane was demarcated on the liver surface by temporary occlusion of the right hepatic artery and right portal vein. Inflow vascular occlusion was not used during liver transection. When the transection of liver approached the liver hilum, the right hepatic duct together with the surrounding Glissonian sheath was encircled. After identification of the confluence of the right and left hepatic ducts, the right hepatic duct was divided near to the confluence of the hepatic ducts by scissors. The divided end at the confluence of the hepatic duct was closed transversely together with the surrounding Glissonian sheath by continuous 5-0 polydioxanone monofilament absorbable suture. The liver transection was carried on down to the junction of the middle hepatic vein with the left hepatic vein or inferior vena cava.

At the time of harvesting, the right portal vein was clamped and cannulated by a catheter connected to cold plasma solution. The right hepatic artery, right hepatic vein(s), and middle hepatic veins were clamped at the junction with the main trunks and divided. Blood that escaped from the graft was recovered and collected in a red cell saver. The stumps of the right hepatic artery, right portal vein, and hepatic veins were closed by continuous nonabsorbable surgical sutures. Methylene blue was injected into the common bile duct via the cystic duct cannula to detect bile leakage from the right hepatic duct stump and transection surface. The falciform ligament was sutured to the anterior abdominal wall to prevent rotation of the left lobe into the right subphrenic cavity. A drain (Reliavac; Davol, CR Bard Inc, Covington, Mexico) was inserted into the right subphrenic cavity before wound closure.

The donors were cared for in the intensive care unit with attention to adequate tissue oxygenation and perfusion. Parenteral nutrition consisting of a mixture of branched-chain amino acid–enriched solution, dextrose, and medium- and long-chain triglycerides was administered in all except the first 2 donors immediately after the hepatectomy to stimulate liver regeneration. Once parenteral nutrition was started, no other intravenous fluid was given, and the central venous pressure was maintained as low as possible to avoid congestion of the liver remnant. Oral nutrition was encouraged once bowel activity returned and the parenteral nutrition was stopped. Chest physiotherapy and incentive spirometry were routinely given. All data were recorded prospectively by a single research assistant.

was returned to donors 2 and 6 only. The volume of blood returned was 300 mL and 750 mL, respectively. None of the donors received platelet and fresh frozen plasma infusion intraoperatively, but donors 3 and 5 received 1040 mL and 540 mL exogenous fresh frozen plasma, respectively, in the postoperative period. The median duration of postoperative hospital stay was 11.5 days (range, 6-38 days). Five donors volunteered to stay longer than 2 weeks to take care of the recipients and their duration of hospital stay was included in the calculation.

Data on the postoperative serum bilirubin, alanine aminotransferase, and aspartate aminotransferase levels are shown in **Figure 2**. The serum bilirubin level of all donors, except donors 2 and 8, returned to the normal level at the end of the first week. The peak serum bilirubin level of donor 2 was 203 µmol/L on postoperative day 3. The peak serum bilirubin level of donor 8 was 318 µmol/L on postoperative day 23. The postoperative international normalized ratio and the platelet count data are shown in **Figure 3**. The international normalized ratio of the donors returned rapidly to the normal level at the end of the first week.

Mild fatty change of liver (<5%) was found on liver histological evaluation in 12 donors (55%) (Table). Moderate fatty change was seen in donor 2 (20%) and donor 8 (15%). These 2 donors developed postoperative cholestasis.

The ratio of the left lobe volume to the total volume of the liver of the donor was calculated on CT volu-

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metry.[2] The remnant left lobes were 27% to 43% of the total liver volume (median, 33%). Donors 8, 16, and 17 had left lobe volume of 27% of the total volume. Only donor 8, whose liver showed 15% steatosis, developed postoperative cholestasis (Table).

There was no donor mortality. Donor 2 developed wound infection due to methicillin-resistant *Staphylococcus aureus* and cholestasis. He subsequently developed an incision hernia that required repair. Donor 3 developed obstructive jaundice 2 months after discharge from the hospital. Endoscopic retrograde cholangiopancreatography showed that she had stricture at the confluence. Fibrosis was found at the liver hilum at laparotomy. She was well after biliary enteric anastomosis constructed at segment III duct. On review of the preoperative hepatic arteriogram, excessive dissection of the right hepatic artery to the left might have been responsible for ischemia of the common hepatic duct. Donor 8 developed cholestasis for 4 weeks. He was otherwise well and eventually free from jaundice. Donor 17 had transient left peroneal nerve palsy. Donor 18 returned to the hospital 34 days after discharge because of a small bowel obstruction. Laparotomy showed a single adhesion band beneath the right subcostal wound. All donors are well and have returned to their previous occupations.

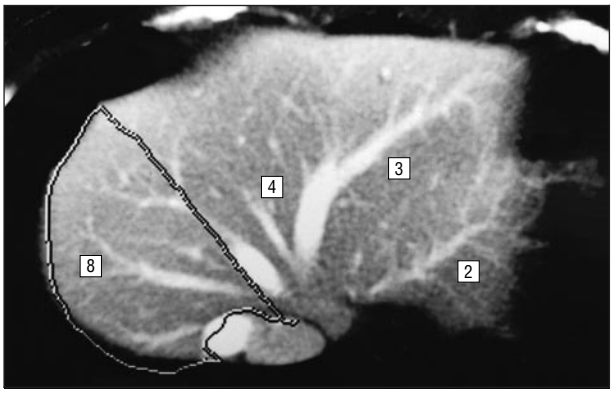

Figure 1. *Computed tomographic scan showing the hepatic vein anatomy in the region of the middle hepatic vein. The segment IV hepatic vein (4) joined the segment III hepatic vein (3) and was vulnerable to injury when transection was performed on the left side of the middle hepatic vein. The segment VIII hepatic vein (8) joined the middle hepatic vein near the inferior vena cava. Two orifices would be expected at the transection plane of the middle hepatic vein. The segment II hepatic vein (2) is separated from the segment III hepatic vein (3). The dotted line indicates the boundary of the right lobe.*

COMMENT

Live donor liver transplantation is performed on the premise that the remnant liver in the donor will regenerate quickly and the donor will not be harmed by the operation. To ensure that the remnant liver will regenerate quickly after the operation, intraoperative trauma to the liver remnant must be minimal. Thus, we exercised careful and intermittent rotation of the right lobe during mobilization,[3] exerted no Pringle maneuver during liver transection, reconstructed the falciform ligament to prevent left lobe rotation into the right subphrenic cavity,[4] and initiated immediate postoperative parenteral nutritional support to stimulate liver regeneration.[5,6]

In live donor liver transplantation using the right lobe, the volume of the remnant liver is a major concern. There were, however, insufficient data in the literature to guide the surgeons in choosing the appropriate candidates for right lobe donation. In animal experiments, it was demonstrated that 10% of viable liver

Donor Data and Postoperative Complications

Donor No.	Blood Loss, mL	Fresh Frozen Plasma, mL	Total Parenteral Nutrition, d	Left Lobe Volume, mL	Left Lobe–Total Volume Ratio	Fatty Change, %	Complication(s)
1	1300	0	0	423	0.36	<5	None
2	738	0	0	586	0.34	20	Cholestasis, MRSA* wound infection, incision hernia
3	900	1040	4	291	0.32	0	Biliary stricture
4	1000	0	3	231	0.34	<5	None
5	800	540	3	472	0.33	0	None
6	1600	0	5	394	0.40	0	None
7	700	0	3	406	0.34	0	None
8	500	0	3	368	0.27	15	Cholestasis
9	1200	0	3	391	0.32	<5	None
10	1000	0	4	365	0.31	<5	None
11	600	0	2	350	0.34	<5	None
12	400	0	2	446	0.43	0	None
13	1200	0	4	306	0.35	0	None
14	300	0	4	466	0.32	<5	None
15	400	0	2	405	0.38	0	None
16	800	0	3	292	0.27	<5	None
17	200	0	5	224	0.27	<5	Transient left peroneal nerve palsy
18	500	0	3	407	0.41	<5	Small bowel obstruction
19	800	0	4	217	0.29	<5	None
20	500	0	3	322	0.31	0	None
21	300	0	3	221	0.32	1	None
22	200	0	2	436	0.39	1	None

**MRSA indicates methicillin-resistant* Staphylococcus aureus.

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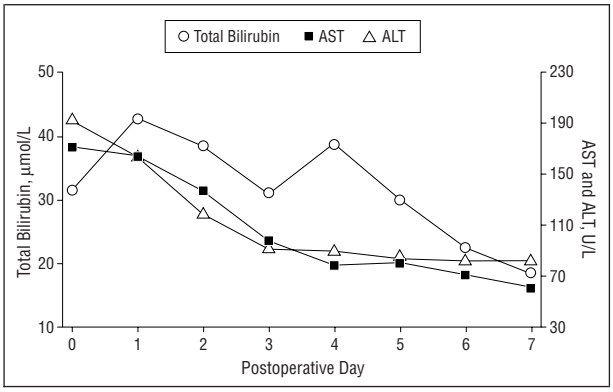

Figure 2. *Median values of serum total bilirubin, aspartate aminotransferase (AST), and alanine aminotransferase (ALT) levels of the donors during the first postoperative week.*

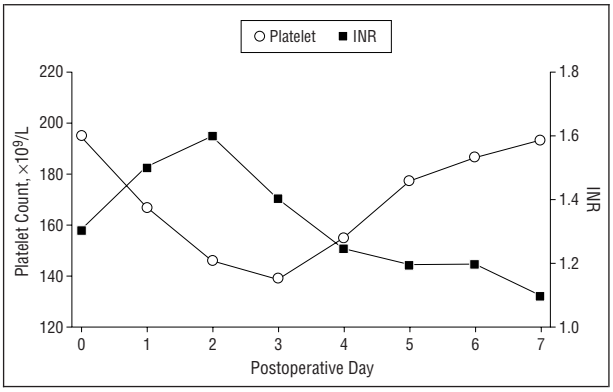

Figure 3. *Median values of platelet count and international normalized ratio (INR) of the donors during the first postoperative week.*

mass was adequate for spontaneous recovery after major hepatectomy.[7] In human situations, many patients survived major hepatectomy of large tumors because the contralateral lobe of liver had undergone hypertrophy before the operation or only a small portion of nontumorous liver was removed together with the large tumor. Before the era of CT volumetry, Stone et al[8] estimated that removal of 70% of the total volume of the liver was well tolerated in patients with normal liver. Recently, Kubota et al,[9] using CT volumetry, showed that individuals with normal liver function could tolerate resection of up to 60% of the nontumorous liver. The present data, albeit limited, indicated that residual liver volume that is 27% of the total volume is the lowest limit that can support survival, provided that the liver itself is not fatty. To allow a safety margin, residual liver volume of 30% of the total volume is probably the lowest limit. In this regard, CT volumetry is necessary for preoperative documentation because the volume of the left lateral segment could be quite variable.

The incidence of fatty liver was surprisingly high among live donors in our locality. Liver grafts with mild degree of fatty change can be used for liver transplantation without ill effect but liver grafts with moderate or severe degree of fatty change will lead to primary graft dysfunction in the recipients.[10] The acceptable upper limit of fatty change in a liver graft was 30%.[11] In partial hepatectomy, a trend toward increased mortality was also reported for patients with moderate to severe steatosis (>30% of hepatocytes containing fat).[12] Although fatty liver may not have serious liver function impairment, fatty livers are probably more vulnerable to injury by general anesthesia[13] and ischemia-reperfusion.[14,15] Although we did not use the Pringle maneuver during liver transection, the left lobe of the liver may sustain ischemic injury during right lobe mobilization because of twisting of the inflow and outflow vascular pedicles. In donor 2, whose liver showed 20% steatosis, the period of liver congestion induced by accidental left hepatic vein clamping might aggravate the injury. Therefore, based on the data of the present series and those reported in the literature on similar subjects, we consider that liver with steatosis of 20% or more, especially when the liver remnant was less than 30% of the total volume, should not be selected for right lobe donor hepatectomy.

The speed of recovery of the donor depends on adequate regeneration of the liver remnant. After hepatectomy, liver regeneration in humans is not immediate. There may be 3 to 5 days between the resection and the initial regenerative events.[16] Before adequate regeneration occurs and before oral nutrition can stimulate increased portal blood flow necessary for liver regeneration,[17,18] we give the donors parenteral nutrition, because in addition to providing nutrients and stimuli for liver regeneration, the parenteral nutritional mixture can also serve as an efficient metabolic vehicle for resolving acute electrolyte and acid-based disturbances[19] and has been shown to prevent deterioration of liver function.[20]

The most important risk to the donor during hepatectomy is bleeding, which can be serious at the deeper plane of transection near to the middle hepatic vein. Severe bleeding is associated with a decrease in hepatic blood flow and ischemic injury.[21] The bleeding volume can be reduced if the central venous pressure is low[22] and the patient is placed in a slightly Trendelenburg position.[23] Bleeding during transection of liver parenchyma can be reduced by using the Pringle maneuver[24] or hemihepatic vascular occlusion[25] but it is uncertain whether inflow vascular occlusion can be safely utilized in donor hepatectomy. Theoretically, inflow vascular occlusion can damage hepatocytes but it was also shown that hepatic venous back-perfusion could maintain viability of hepatocytes during the Pringle maneuver.[26] Before more data are available, we would continue the present practice of transecting the liver without the Pringle maneuver.

Another risk to the donor is injury to the bile duct resulting in biliary stricture or leakage. Ischemia due to excessive right hepatic artery dissection is probably responsible for such complication in one of our donors. To avoid such a complication, we consider that the dissection of the right hepatic artery should be confined to the right side of the common hepatic duct. It is also important not to isolate the right hepatic artery too far into the right side of the liver hilum to avoid devascularization of the right hepatic duct. The length of the right hepatic artery available for the right lobe graft might be short but usually was sufficiently long for subsequent microvascular anastomosis.

To protect the donor from contracting viral infection, avoidance of exogenous blood or blood product

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transfusion is the goal. In the present series, one donor received homologous blood transfusion intraoperatively and 2 donors received fresh frozen plasma postoperatively. The transfusion arose out of lack of communication. With expansion of activities of the liver transplant program in our hospital and awareness of potential harmful effect of exogenous blood transfusion by all members of the team, the risk of exogenous blood and blood product transfusion were completely eliminated in the later part of this series.

In conclusion, the live donation of right lobe graft for adult-to-adult liver transplantation is safe provided that the residual liver volume of the donor exceeds 30% of the total liver volume, the liver itself is not fatty, and there is no injury to the liver remnant.

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