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Adult-to-Adult Living Donor Liver Transplantation Using Extended Right Lobe Grafts

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Objective

The authors report their experience with living donor liver transplantation (LDLT) using extended right lobe grafts for adult patients under high-urgency situations.

Summary Background Data

The efficacy of LDLT in the treatment of children has been established. The major limitation of adult-to-adult LDLT is the adequacy of the graft size. A left lobe graft from a relatively small volunteer donor will not meet the metabolic demand of a larger recipient.

Methods

From May 1996 to November 1996, seven LDLTs, using extended right lobe grafts, were performed under high-urgency situations. All recipients were in intensive care units before transplantation with five having acute renal failure, three on mechanical ventilation, and all with hepatic encephalopathy. The median body weight for the donors and recipients was 58 kg (range, 41–84 kg) and 65 kg (range, 53–90 kg), respectively. The body weights of four donors were less than those of the corresponding recipients, and the lowest donor-to-recipient body weight ratio was 0.62:1. The extended right lobe graft was chosen because the left lobe volume was <40% of the ideal liver mass of the recipient.

Results

Median blood loss for the donors was 900 mL (range, 700–1600 mL) and hospital stay was 19 days (range, 8–22 days). Homologous blood transfusion was not required. Two donors had complications (one incisional hernia and one bile duct stricture) requiring reoperation after discharge. All were well with normal liver function 5 to 10 months after surgery. The graft weight ranged from 490 g to 1140 g. All grafts showed immediate function with normalization of prothrombin time and recovery of conscious state of the recipients. There was no vascular complication, but six recipients required reoperation. One recipient died of systemic candidiasis 16 days after transplantation and 6 (86%) were alive with the original graft at a median follow-up of 6.5 months (range, 5–10 months).

Conclusions

When performed by a team with experience in hepatectomy and transplantation, LDLT, using an extended right lobe graft, can achieve superior results. The technique extends the success of LDLT from pediatric recipients to adult recipients and opens a new donor pool for adults to receive a timely graft of adequate function.

Living donor liver transplantation (LDLT) has been established as an excellent treatment method for children with end-stage liver disease.[1-3] This surgical innovation has significantly reduced the pretransplantation mortality for children in Western countries and has provided the only source of organs for transplantation in countries where cadaveric organ procurement is severely restricted. Extension of LDLT from pediatric recipients to adult patients has been made only with limited success largely because of the inability of a relatively small left lobe graft to meet the metabolic demand of an adult recipient. Emond et al.[2] estimated that 50% of the ideal liver mass was the minimum graft volume required to provide adequate functional hepatocytes. Although we previously have reported a successful adult-to-adult LDLT using a left lobe graft as small as 25% of the recipient's ideal liver weight,[4] these small-for-size grafts are prone to dysfunction.[5] With the use of a left lobe graft, successful adult recipients are restricted to those with a body weight <60 kg, usually of the female gender,[4,6,7] and LDLT is not possible if the size of the volunteer donor is smaller than that of the recipient. One possible solution to this problem is to increase the extent of resection in the donor by harvesting the right lobe of the liver, which accounts for 60% to 70% of the total liver mass. There were three LDLTs using a right lobe graft reported in the literature,[8,9] without any successful adult-to-adult cases. Based on our experience in hepatic resection and LDLT, we believe that this may be a viable option to overcome the extreme scarcity of cadaveric organ donors. After our first success in May 1996[10] in using an extended right lobe graft from a living donor for a 90-kg man with fulminant Wilson's disease, we have continued to apply the same technique to appropriate patients. The aim of this article is to report our experience with LDLT using extended right lobe grafts for seven adult patients and to evaluate the possible impact of this technique on the future development of adult-to-adult LDLT.

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PATIENTS AND METHODS

Between May 1996 and November 1996, 18 liver transplantations were performed for 18 patients at the University of Hong Kong, Queen Mary Hospital. Eight whole organ cadaveric grafts and 10 partial living donor grafts were used. Of the 10 LDLTs, 3 pediatric patients received left lateral segment grafts under elective situations, and 7 adult patients in high-urgency status (United Network for Organ Sharing status 1) received extended right lobe grafts from living donors. These seven adult-to-adult LDLTs were the subjects of the current study. The demographics of the recipients and donors are listed in Table 1. The causes of liver failure were hepatitis B infection in five patients, paracetamol overdose in one, and fulminant Wilson's disease in one patient. The donors included three siblings, two fathers, and two wives. The median body weight for the donors was 58 kg (range, 41–84 kg) and for the recipients was 65 kg (range, 53–90 kg). The body weights of four donors were less than those of the corresponding recipients and the lowest donor-to-recipient body weight ratio was 0.62:1 (donor, 41 kg; recipient, 66 kg).

Pretransplant Management

The evaluation and management followed the same protocol as for any patient who was considered for transplantation in high-urgency status. All seven patients required admission to the intensive care unit before transplantation. In each case, moderate-to-severe hepatic encephalopathy was evident (Table 1). Two patients were monitored via intracranial pressure monitors and three patients with stage IV encephalopathy were on mechanical ventilation. Acute renal failure developed in five patients and hemodialysis or continuous venovenous hemofiltration was performed in four. The decision for "listing" a patient for transplantation was based on progressive deterioration in mental status and hepatic failure. The median serum total bilirubin level was 759 μmol/L (range, 192–1207 μmol/L), and the prothrombin time before transplantation was 47 seconds (range, 32.2–128 seconds).

Donor Selection and Informed Consent

The primary selection criterion for a living liver donor was voluntary and informed consent. When the decision for listing was made, the family members were informed

Table 1. PATIENT DEMOGRAPHICS AND STATUS AT TRANSPLANTATION

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7
Recipient							
Sex	M	M	M	M	M	M	F
Age (yr)	28	23	40	34	17	47	20
Body weight (kg)	90	69	66	64	59	65	53
Diagnosis	FWD	HBV	HBV	HBV	HBV	HBV	Drug
Encephalopathy (stage)	2	2	4	4	4	3	3
Mechanical ventilation	No	No	Yes	Yes	Yes	No	No
Renal failure	No	Yes	Yes	Yes	No	Yes	Yes
Total bilirubin (μmol/L)	1209	957	879	540	393	759	192
Prothrombin time (sec)	32.2	36.8	47	58.7	50	33.8	128
Donor							
Sex	M	M	F	F	M	F	M
Age (yr)	30	47	35	30	51	44	29
Body weight (kg)	74	84	41	42	61	48	58
Donor/recipient weight ratio	0.82	1.22	0.62	0.66	1.03	0.74	1.09
Relation	Brother	Father	Wife	Sister	Father	Wife	Brother

FWD = fulminant Wilson's disease; HBV = hepatitis B virus.

of the need for an early cadaveric liver transplantation. To reduce the pressure to volunteer, no suggestion for LDLT was made. If, however, the family members raised the option of LDLT, the risks and benefits of the procedure would be explained in general without mentioning anyone as a potentially suitable donor. Family members with an apparent wish for voluntary donation were assessed by a clinical psychologist and were further counseled, with particular emphasis on all possible risks of the donor hepatectomy. Finally, informed consent was obtained from the volunteer donor in the absence of other family members. The donor was informed that he/she might withdraw at any time and the transplant team would help by putting forward a medical or technical reason to release the pressure on him/her. It was only after informed consent was made that the volunteer donor was evaluated for medical or surgical suitability.

Donor Evaluation

Thorough medical examination was performed to assess the donor's liver function and fitness for major hepatic resection. Serology for viral hepatitis was negative, and ABO blood group compatibility was mandatory. Computed tomography with volumetry was performed to determine the size of the left and right lobes of the liver. The extended right lobe graft was chosen because the estimated left lobe volume (median, 26%; range, 11%–35%) was <40% of the recipient's estimated standard liver mass.[11] Finally, celiac and superior mesenteric angiography was performed to delineate the vascular anatomy. The median time from listing to informed consent for LDLT was 36 hours (range, 14–174 hours) and from informed consent to LDLT 15 hours (range, 7–84 hours).

Surgical Procedures

The donor hepatectomy (Fig. 1A) consisted of an extended right lobectomy performed through a bilateral subcostal incision with median extension to the xyphoid. To avoid homologous blood transfusion, autologous blood was collected from the donor on induction of anesthesia, and a cell saver was used to collect blood lost during operation. Intraoperative ultrasound examination was performed to identify the major vascular structures of the liver. Special attention was paid to the anatomy of the junction of the middle and left hepatic veins and the possible existence of a right inferior hepatic vein. Cholecystectomy and intraoperative cholangiogram were performed to delineate any biliary tract anomaly, particularly the variation in the drainage of the right posterior segment duct.

Dissection at the right side of the liver hilum exposes the right hepatic artery. In the first three cases of the series, the right hepatic artery was dissected free and traced from the right side to the left side of the common bile duct until the junction with the common hepatic artery was identified. This involved the division of a number of arterial branches supplying the bile duct. In the last four cases, the right hepatic artery was dissected free to

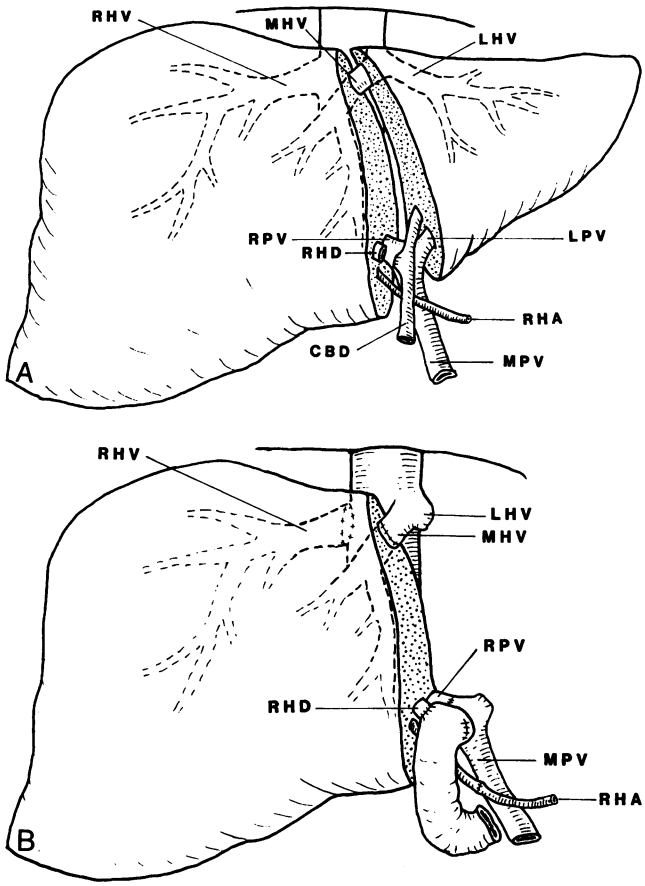

Figure 1. (A) Donor operation. (B) Implantation of the graft. RHV = right hepatic vein, MHV = middle hepatic vein, LHV = left hepatic vein, MPV = main portal vein, RPV = right portal vein, LPV = left portal vein, RHA = right hepatic artery, RHD = right hepatic duct, CBD = common bile duct.

the right side of the common bile duct only. The right portal vein was freed and individual branches to the caudate lobe were divided between ligatures. The right lobe of the liver then was mobilized, and the right hepatic vein was isolated outside the liver. The right inferior hepatic vein, if present, was isolated and preserved.

Compared to the case of a right lobe graft with single right hepatic vein drainage as reported by Yamaoka et al.,[12] the extended right lobe graft (segments V, VI, VII, and VIII, and a rim of segment IV) included the middle hepatic vein drainage as well. The line of parenchymal transection was marked on the surface of the liver after the line of demarcation produced by temporary compression of the right hepatic artery and portal vein. Parenchymal transection was performed on the left side of the middle hepatic vein using an ultrasonic dissector without vascular inflow occlusion for either side of the liver. The right hepatic duct was severed close to the cut surface of the liver without disturbing the surrounding Glissonian sheath. The middle hepatic vein was completely isolated at its junction with the left hepatic vein. Continuation of the parenchymal transection was made until the graft became completely detached, except for the right hepatic artery, right portal vein, right and middle hepatic veins, and, in donor 5, an additional right inferior hepatic vein. The right portal vein, right hepatic artery, and hepatic veins then were individually clamped and divided. The liver graft was flushed immediately with cold University of Wisconsin solution through the portal vein on the back table. The bile duct also was rinsed, but to avoid damage to the intima of the hepatic artery, cannulation and flushing of the artery was not performed. In the first two cases, the stumps of the hepatic veins were prepared using an ultrasonic dissector to ensure an adequate length for anastomosis. However, this resulted in troublesome bleeding around the hepatic veins on reperfusion. Since then, we had stopped performing this additional dissection, and only fibrin glue was sprayed on the cut surface of the graft on the back table.

The recipient total hepatectomy was performed under venovenous bypass with preservation of the inferior vena cava. Special modifications directed toward preservation of an adequate length of inflow and outflow vessels were required to facilitate subsequent vascular anastomosis. The individual hepatic arteries were dissected free at the liver hilum and divided as close to the liver as possible. The confluence of the main portal vein was freed, and the maximum length of right and left portal veins was preserved. Portal venous bypass was established by means of a cannula inserted through the left portal vein into the main portal vein. The liver was dissected from the inferior vena cava, and the hepatic veins were divided inside the liver substance to complete the total hepatectomy. The stumps of the right and middle hepatic veins were preserved by trimming the surrounding residual liver tissue, and the left hepatic vein stump was sutured.

Implantation (Fig. 1B) started with end-to-end right hepatic vein followed by middle hepatic vein anastomosis using polypropylene sutures. In recipient 5, an additional 10-mm diameter right inferior hepatic vein was anastomosed directly to the inferior vena cava. Direct right portal vein end-to-end anastomosis was performed without interruption of the portal venous bypass via the left portal vein cannula. After reperfusion and hemostasis, hepatic artery anastomosis was performed using microvascular technique. In recipient 1, separate right anterior segment and right posterior segment hepatic arteries of the graft were anastomosed to the left and right hepatic arteries of the recipient, respectively. An interposition graft was not required in any of the vascular anastomoses. An end-to-side hepaticojejunostomy (double in three patients) Roux-en-Y was performed with an internal stent. The median cold ischemic time

Table 2. GRAFT WEIGHT, OPERATIVE DATA, AND OUTCOME

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Graft							
Graft weight (g)	910	1140	710	490	860	580	740
Graft/recipient weight ratio	0.01	0.017	0.011	0.007	0.015	0.009	0.014
Graft weight/ESLM ratio	0.47	0.68	0.48	0.32	0.56	0.38	0.54
Cold ischemic time (min)	114	114	110	109	104	131	82
Donor							
Operation time (hr)	14.5	13	13.5	10	11	11.5	11.5
Blood loss (mL)	1300	740	900	1000	800	1600	700
Peak AST (IU/L)	204	215	91	313	135	289	189
Peak serum total bilirubin (μmol/L)	62	203	55	45	57	45	61
Hospital stay (days)	11	22	22	8	21	19	8
Recipient							
Operation time (hr)	21	17.5	16	19	15.5	16	14.5
Peak AST (IU/L)	1217	604	455	287	445	202	693
PT (sec)							
Day 1	22.7	19.3	18.8	22.2	16.6	18.1	18.3
Day 3	16.7	14.8	14.8	14.7	11.3	17.8	16.0
Day 7	14.3	12.7	16.6	14.5	13.3	11.3	11.4
Outcome	Alive	Alive	Alive	Died	Alive	Alive	Alive
Follow-up	10 mo	9 mo	7 mo	16 days	6 mo	6 mo	5 mo

ESLM = estimated standard liver mass; AST = aspartate aminotransferase; PT = prothrombin time.

was 110 minutes (range, 82–131 minutes). On completion of all vascular anastomoses and on closure of the abdomen, an intraoperative Doppler ultrasound examination was performed. Histologic examination results of the explanted liver showed massive hepatic necrosis in all recipients with evidence of preexisting bridging fibrosis in four.

Postoperative Management

Percutaneous Doppler ultrasound examination was performed daily for 3 days and then whenever clinically indicated. Induction and maintenance immunosuppression consisted of a double regimen of steroid and cyclosporine with the addition of azathioprine in two recipients. In five recipients with acute renal failure, OKT3 induction was used to replace cyclosporine. A protocol percutaneous liver biopsy was performed 5 to 7 days after operation and as clinically indicated.

RESULTS

Donor Operation and Complications

The median blood loss for the donors was 900 mL (range, 700–1600 mL) (Table 2), and it was replaced by autologous blood in three cases. No homologous blood transfusion was required. The operation time was 11.5 hours (range, 10–14.5 hours) and the hospital stay was 19 days (range, 8–22 days). Many donors preferred to stay in hospital longer for the sake of taking care of the recipients. Complications occurred in two donors (Table 3). Donor 2 had normal preoperative liver function test results and imaging studies, but the results from a biopsy

Table 3. POSTOPERATIVE COMPLICATIONS

	Number
Donor	
Incisional hernia*	1
Bile duct stricture*	1
Recipient	
Biliary stricture*	2
Biliary leakage†	1
Intra-abdominal abscess†	1
Acute pancreatitis†	1
Acute appendicitis†	1
Postbiopsy bleeding†	1
Abdominal candidiasis†	1
Cerebral vascular accident	1

* Delayed complications (>30 days) requiring reoperation.
† Early complications (≤30 days) requiring reoperation.

of the graft showed mild degree of fatty change. Postoperative wound infection and hyperbilirubinemia developed in donor 2 (peak total bilirubin, 203 μmol/L, day 2). The liver function returned to normal spontaneously, and he was discharged on postoperative day 22. Subsequently, incisional hernia developed in him and this was repaired 3 months after operation. Donor 3, on follow-up, had persistent elevation of liver enzymes without jaundice. An ultrasound scan showed a dilated biliary tree, and a percutaneous transhepatic cholangiogram showed stricture of the left hepatic duct. Segment III bilioenteric bypass was performed 2 months after discharge and her liver function returned to normal. Currently, all donors were well with completely normal liver function at 5 to 10 months after operation, and all had returned to their previous level of activities. Six donors resumed their previous job and one was seeking a new job.

Graft Weight and Functions

The median time for the recipient operation was 16 hours (range, 14.5–21 hours). The median graft weight was 740 g (range, 490–1140 g) and amounted to 1.1% (range, 0.7%–1.7%) of the recipient body weight (Table 2). The graft-weight-to-estimated-standard-liver-mass ratio ranged from 32% to 68%. All grafts showed immediate function with good bile production, and all recipients regained normal consciousness within 7 days after transplantation. The peak serum aspartate aminotransferase level was 455 international units/L (range, 202–1217 international units/L). The median prothrombin time was 18.8 seconds at day 1, 14.8 seconds at day 3, and 13.3 seconds at day 7.

Recipient Complications and Survival

The overall postoperative complications rate was 86%. There was no vascular complication, but six recipients had complications requiring reoperation in the early postoperative period (Table 3). Recipient 3 regained normal consciousness with no neurologic deficit 5 days after transplantation. He required two re-explorations because of biliary leakage and cerebral vascular accident developed, resulting in dysphasia and mild hemiparesis after the last reoperation. The other five recipients underwent early reoperation, mainly for intra-abdominal sepsis and bleeding. In addition, two recipients had biliary stricture necessitating revision of hepaticojejunostomy 5 and 6 months after transplantation, respectively.

Six (86%) of seven recipients were alive with the original graft and had normal liver function at a median follow-up of 6.5 months (range, 5–10 months). Recipient 4, who had liver failure due to hepatitis B infection after renal transplantation, was receiving immunosuppressive therapy before LDLT. He received from his sister a right lobe graft of 490 g, which represented 32% of his ideal liver weight. Reoperation for intra-abdominal sepsis was performed 5 days after transplantation and abdominal candidiasis was discovered. Despite a functioning liver graft, he died of systemic candidiasis 16 days after transplantation. Except for recipient 3, who suffered from dysphasia due to postoperative cerebral vascular accident, all survivors recovered without any neurologic sequelae. Three had resumed work and two rejoined their studies in school.

DISCUSSION

The success of liver transplantation has resulted in a wider application of this life-saving operation. Despite maximal access to potential donors, the number of cadaveric organ donors cannot keep pace with the rapid increase in demand. The disparity between supply and demand for donor organs has led to the development of innovative surgical techniques, including reduced-size liver transplantation,[13,14] split-liver transplantation,[15–17] and living donor liver transplantation.[1–3,18] Reduced-size liver transplantation diverts the limited organ supply from adult to pediatric patients without increasing the absolute number of available grafts. Although split-liver transplantation offers the attractive concept of transplanting two patients with one donor liver, only children, or occasionally, small adult patients benefit from the additional left lateral segment graft provided by splitting. Similarly, LDLT, using a left lobe graft, is successful mainly in providing an alternate source of grafts for pediatric patients. Thus, none of these methods can address the crisis of increasing scarcity of donor organs for adult patients.

When adult-to-adult LDLT was attempted using a left lobe graft, the small-for-size graft suffered significant functional impairment[5] and could not provide adequate hepatic function for a relatively large recipient. Several alternative strategies have been suggested. Artificial liver support devices can theoretically maintain the patient's life until the graft regenerates. However, there is, as yet, no support device proved to be effective under such clinical circumstances. In addition, the small-for-size graft fails not only because of inadequate functional hepatic mass but also sustains injury, which is thought to be related to the excessive portal perfusion and the increased amounts of gut-derived endotoxin and substrates.[5] Alternatively, auxiliary orthotopic or heterotopic transplantation using a left lobe liver graft from a living donor has been proposed.[19] Experience from cadaveric auxiliary orthotopic transplantation showed that this hypothesis would not be feasible, except in patients undergoing transplantation for metabolic diseases. In the majority of patients with acute or chronic liver failure, the small graft would not be able to provide adequate immediate function. Bismuth et al.[20] showed that a small auxiliary liver

graft could not arrest neurologic damage in patients with fulminant hepatic failure, and Boudjema et al.[21] suggested the use of a right lobe auxiliary graft to provide sufficient functional hepatocytes when the recipient and donor were size-matched. Finally, a more realistic approach to extend the benefit of LDLT to adult recipients is to increase the extent of resection in the donor by harvesting the right lobe. Nevertheless, the risks to the donor are thereby increased,[9] and the ethical considerations would need to be re-evaluated.

The ethical issues of LDLT have always centered on the balance of the risks and benefits both for the recipient as well as for the donor.[22] For the recipient on high-urgency status, the benefit of a timely transplantation using a right lobe graft from a living donor is overwhelming. Even in countries in which cadaveric liver transplantation is well developed, there is a high risk of a patient dying before an organ becomes available.[23–25] In most parts of Asia, including Hong Kong, where for various religious and cultural reasons, organ transplantation from brain-dead donor is severely restricted, living donors are practically the only source of grafts available to salvage these patients who otherwise would have no chance of survival.[4,6,26,27] When the volunteer donor is relatively small for the recipient and the estimated left lobe graft volume is <40% of the recipient's ideal liver mass, a left lobe graft may not be able to meet the recipient's metabolic need, and the recipient is potentially at risk for graft failure. By providing a graft of adequate volume and of excellent quality at the optimal time, LDLT, using an extended right lobe graft, rapidly restored liver function and reversed encephalopathy. Apart from recipient 3 in whom dysphasia developed after postoperative cerebral vascular accident, all the recipients had full neurologic recovery. Despite the very high urgency status of our patients, we were able to achieve a patient survival rate of 86% without the need for retransplantation.

For the donor, the major issue of concern in LDLT using an extended right lobe graft lies in the greater extent of the donor operation with a perceived higher risk. Even in left lobe LDLT, the possibility of donor mortality is real and at least one has been reported.[28] It is difficult to determine the precise risk of an extended right hepatic lobectomy in a healthy donor. We estimate the mortality risk in expert hands to be <2%. Because a living donor is placed at extra risks, we believe that it is ethically acceptable only if the procedure is applied as a last remedy to patients on high-urgency status. Because a cadaveric graft remains an option for adult patients waiting for elective transplantation, there is virtually no family member who would see the need to take the risk of being a living liver donor. Conversely, the benefit to a living liver donor comes solely from the satisfaction of saving a beloved family member's life and the gain in self-esteem. The risks and suffering for the donor are justified only when the operation has a good chance of resulting in the recovery of the patient. Our results showed that excellent survival can be achieved for desperately ill patients using the current technique. The question of whether the benefits of the high success rate outweigh the extra risks is open to debate, but a country's sociocultural background, availability of cadaveric grafts together with the patient's family relations should be taken into consideration. With the knowledge of the favorable result of this technique, the question in our institution now becomes whether it is ethical to deprive a person of his right to take some risk to save the life of a loved one. The informed donor ultimately may be the best qualified person to make the final judgment.[29]

Regarding the informed consent in an emergency situation, the pressure on the donor is mainly internal rather than external. The benefit of graft availability outweighs concerns about coercion of donors, but it is our policy that family members should not be solicited for donation.[4] The initiation and decision for donation should be based primarily on a family member's voluntary intent. To avoid coerced donation by medical and anatomic factors, donor assessment should be performed only after the donor's voluntary intent has been clearly shown and informed consent executed. A person should elect to be a donor only because he wishes to, not because he is found to be suitable. The availability of LDLT using extended right lobe grafts implies that undue external pressure would not be put on those family members who have the "right" body build.

Three LDLTs using right lobe grafts without middle hepatic vein drainage were recorded by the International Living Liver Donor Registry.[8] In the successful case from the Kyoto series,[12] a right lobe graft weighing 625 g was transplanted to a 9-year-old girl. When such a right lobe graft with right hepatic vein drainage alone is used for an adult recipient, the graft is susceptible to damage by the relatively large volume of portal venous blood flow. An extended right lobe liver graft, with the additional venous drainage provided by the middle hepatic vein, avoids this problem and offers superior graft function even for a large recipient. The necessity of the middle hepatic vein drainage clearly was shown in the first case of our series when the graft became extremely congested after reperfusion was established with right hepatic vein drainage alone.[10] In the presence of a right inferior hepatic vein, the vein also should be preserved and additional venous drainage established.

An extended right lobe LDLT demands the highest degree of technical skill in hepatectomy and transplantation. In the donor, the greatest challenge is the completion of the parenchymal transection and isolation of the right and middle hepatic veins without any interruption of the

inflow and outflow vessels of both sides. The ability to master the technique of the anterior approach[30] in right-sided hepatectomy for tumors forms the basis for this donor operation.[31] Initially, in an attempt to lengthen the inflow and outflow vessels of the graft, we dissected the right hepatic artery down to the junction with the common hepatic artery and used the ultrasonic dissector to prepare the stumps of the hepatic veins on the back table. The former dissection devascularized the bile duct and probably has contributed to the bile duct stricture in one donor, whereas the latter resulted in troublesome bleeding on reperfusion. We have now stopped performing either of these dissections. By carefully preserving an adequate length of inflow and outflow vessels during the recipient total hepatectomy, all the vascular anastomoses were accomplished without the need for any interposition graft.

Our experience shows that outstanding survival can be achieved in selected patients using an extended right lobe liver graft from a living donor. The results are comparable to the best possible outcome in cadaveric transplantation for patients with similar high-urgency status.[32] We believe that this can be attributed to two factors. First, a volunteer living donor provides a readily available source of graft of excellent function and allows for optimal timing of transplantation before the development of irreversible complications. Without the restriction imposed by the body build, the primary selection criterion is the donor's voluntary intent. As soon as informed consent is available, evaluation and assessment can be completed and transplantation performed within 24 hours. Second, a graft from a living donor provides excellent function because of the short ischemic time and the lack of adverse factors found in cadaveric donors. Apart from its greater functional liver volume, an extended right lobe liver graft has additional advantages over the left lobe liver graft, which contributes to the improved graft function.[10] The graft fits into the right subphrenic space of the recipient and will not be compressed by the retraction force during hepatic artery anastomosis or on closure of the abdomen.

CONCLUSIONS

The current series represents the first successful attempt in extending LDLT to adult patients of all sizes. The technique of extended right lobe liver grafts from living donors basically overcomes the restriction imposed by the donor-to-recipient size match and provides a new option for adult patients to receive a liver graft of adequate size and function. However, experience with this technique still is limited. The high re-exploration rate for biliary complication in the recipients indicates that our technique needs further improvement. Most important of all, the extra risk for the donor remains the major concern, and the greatest expertise in hepatic resection technique is required to maximize the donor's safety. At present, the procedure only should be attempted as a last remedy in transplant centers with adequate experience in hepatectomy. Its role in the future development of adult-to-adult LDLT remains to be defined.

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Discussion

DR. RONALD W. BUSUTTIL (Los Angeles, California): I wish to congratulate Dr. Fan for his presentation and thank him for providing me with a manuscript that beautifully details this very complex procedure of living-related liver transplantation using an extended right hepatic lobectomy in adult liver grafting. Clearly one could only justify this procedure in the most desperate of conditions.

In fact, this paper is perhaps most aptly put into perspective by Shakespeare's *Hamlet.* "Diseases desperate grown by desperate appliance are relived or not at all."

The scarcity of donors with which Dr. Fan and his colleagues are faced in Hong Kong, along with their other Asian colleagues, is virtually insurmountable. Because of the cultural and religious reasons in that part of the world, cadaveric organ donation is highly restricted. This situation imposes a need to explore rather extreme solutions to the problem of patients dying with liver failure.

However, what is extreme today may become standard practice tomorrow as new advances are perfected and applied. The precedent for this has already been set in this specific field of endeavor with the successful application of living-related liver transplantation in children.

When this technique was first introduced in 1988, skepticism was rampant. I was one of the most vocal skeptics. However, in 1997, living-related transplantation in children is an established procedure with close to 1000 cases being performed with excellent results in the recipient and rare morbidity in the donor.

It is the donor morbidity and mortality that is the crux of this issue that Dr. Fan has presented. In living-related liver donation as it is applied to children, segments 2 and 3 of the liver or the left lateral segment are removed for transplantation in the child. This represents at most 25% of the liver volume and does not require extensive dissection in the hilum. Liver failure of the donor has not been seen in close to 1000 cases, and major complications are rare. On the other hand, in the procedure described by the authors, 60% to 80% of the liver volume is removed, which presents a much more significant risk to the donor.

Extended right hepatic lobectomy performed as a therapeutic procedure for both benign and malignant diseases can indeed be associated with severe complications, namely portal vein thrombosis, bile duct stricture, and persistent cholestatic syndrome. The authors did in fact encounter these sinister complications in their series of seven cases. One donor patient suffered from liver dysfunction and hyperbilirubinemia lasting 3 weeks, and another required reoperation for a biliary stricture. In a larger series, I would suspect that a significant complication rate may be even higher than the 28% reported by the authors, which in my view would not justify usage in our own center.

Regarding the results in the recipients, the authors are to be congratulated in rescuing six of seven patients who would have surely died otherwise. However, again I am troubled by the high morbidity rate. Five of seven patients required reoperation for bleeding or sepsis, two of seven developed biliary strictures. Could the authors speculate on these problems? This rate of reoperation seems excessive when viewed in the light of other series of split-liver transplantation and liver-relating grafting.

Finally, I believe the authors' approach to obtaining consent for this procedure must be lauded. There clearly was no hint of coercion because the donor was never approached until he or she requested information regarding living-related donation. This position I believe is absolutely essential for an ethically based program of living-related donations.

I would like to conclude by asking you, Dr. Fan, several questions.

First, the mean operative time is quite long, 12 hours for the donor and 17 hours for the recipient. Do you think this has contributed to your complication rate? What is your strategy to improve it?

Second, usually bleeding from the cut surface of the liver after living-related transplantation or *in situ* split liver transplantation is uncommon. To what do you contribute your high incidence of bleeding postoperatively? Is this in part due to the fact that you resect liver tissue around the hepatic veins?

Third, you strive for 40% of the required liver mass. Does this vary according to the cause of liver failure? In other words, would a patient with end-stage liver disease from acute liver failure require more than that which would be seen in a patient who has chronic liver failure?

DR. AINSLIE G. R. SHEIL (Sydney, Australia): I too would like to compliment you on this important work and ask my questions from a somewhat different aspect. I think I belong to one of a number of surgeons who, for maybe 30 years or so,