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ORIGINAL ARTICLE

Safety of modified extended right hepatectomy in living liver donors

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Summary

In living donor liver transplantation (LDLT), the standard right graft has been adopted by many centers to meet the metabolic demands of large recipients. In conventional right liver graft, congestion at anterior section may be problematic especially when graft volume is insufficient. We previously introduced a technical aspect of modified extended right hepatectomy (MERH), in which the middle hepatic vein was excavated by preserving the entire segment 4 (Sg4) to the donor. In this report, we investigated the safety of donors who received MERH. Between August 2002 and July 2005, 97 donors underwent right liver donation. MERH was considered when remnant-left liver volume exceeded 35% of whole liver. Eighteen donors underwent MERH (MERH group, $n = 18$). We compared the clinical outcomes of MERH group with those of donors who underwent conventional right hepatectomy (RH) with remnant liver volume exceeding 35% (RH group, $n = 37$). No donor mortality occurred. No intra-operative transfusion and no re-operation were performed. There were no differences in operative time (290.8 min in MERH group vs. 297.0 min in RH group, respectively), blood loss (453.3 ml vs. 426.5 ml), and postoperative hospital stay (12.5 days vs. 12.8 days) between the two groups ($P > 0.05$). Period of drain removal was longer in MERH group (12.5 days vs. 9.4 days, $P < 0.05$). But, there was no difference in complication rate between the two groups (11/18 vs. 23/37, $P > 0.05$). Computed tomography scan showed that congestion of Sg4 was occurred in 13 out of 18 MERH donors in early postoperative period, but all recovered at 4 months. The regeneration of the remnant liver after MERH and RH were similar (209.8% vs. 200.0% at 4 months, $P > 0.05$). Our results show that MERH did not impair recovery or liver regeneration in donors, and indicate that MERH can be safely done in adult LDLT when the remnant liver exceeds 35%.

Introduction

Recently, living donor liver transplantation (LDLT) for adult patients has been performed worldwide [1]. Size mismatch remains a major obstacle to the expansion of LDLT to adult recipients [2]. In LDLT, the standard right graft has been adopted by many centers to meet the metabolic demands of large recipients. This procedure can result in potential congestion in the anterior section of the right graft, because the middle hepatic vein (MHV) remains on the donor side, which constitutes the main drainage vein for the right anterior section and segment 4 (Sg4) [3–6]. Congestion at anterior section might be problematic especially when the graft volume is insufficient.

Some investigators have advocated modified right liver graft, in which the MHV tributaries from the anterior section drain to the recipient MHV using vascular grafts, when sizable MHV tributaries are encountered [5,6]. However, this procedure is not always effective [6]. The major branches of segments 5 and 8 should be anastomosed to the recipient's deep-seat MHV stump. A relatively long segment bridging a low-pressure venous system would be more prone to thrombosis. It requires additional vessels and is a time-consuming procedure to prolong warm ischemic time. Others have opted to perform the extended right hepatectomy, including the MHV and some portion of Sg4 in the graft [7–9]. This can alleviate the problem of graft congestion and allow a larger graft to be obtained. But, the remnant donor liver is often too small and remnant Sg4 portion becomes congested.

We previously introduced the technical refinement of a modified extended right hepatectomy (MERH), in which the MHV was excavated by preserving the entire left medial section (Sg4) to the donor [10]. Indications for MERH in donor hepatectomy are when the graft volume is insufficient for recipients, remnant liver volume exceeds 35% of the whole liver, and donor steatosis is absent.

Modified extended right hepatectomy in donor hepatectomy has several advantages. Firstly, this procedure guarantees good venous drainage and optimal graft function. Secondly, this procedure can ensure the safety of the donor because of preservation of entire Sg4 of the donor. Thirdly, it is not technically demanding too much. Fourthly, it consumes little operation time. Fifthly, if intersegmental vein is present, no severe congestion of S4 occurs [10].

In this report, we investigated the safety of the donors who received MERH.

Patients and methods

Between August 2002 and July 2005, 97 live donors underwent right hepatectomy (RH) at our institution. Remnant-left liver volume was estimated as exceeding 35% in 55 donors. We performed MERH when recipient condition was poor and when donor remnant liver volume exceeded 35% of whole liver volume without steatosis [10]. Eighteen donors underwent MERH. These donors were classified as MERH group ($n = 18$). At the same period, 37 donors whose remnant liver volumes exceeded 35% underwent conventional RH. These donors were classified as RH group ($n = 37$).

Male-to-female ratio was similar in both groups (30:7 in RH group and 13:5 in MERH group, $P = 0.50$).

Mean ages of both groups were similar too (28.8 ± 9.1 years in RH group and 32.7 ± 11.9 years in MERH group). Pre-operatively measured remnant volumes were not different in both groups (38.6 ± 2.8% of whole liver in RH group, and 37.1 ± 3.0% of whole liver in MERH group, $P = 0.09$). At the operation room, we performed liver wedge biopsy before doing donor hepatectomy and checked steatosis of liver by frozen biopsy.

Table 1. Donors' demographics.

	Right hepatectomy group ($n = 37$)	Modified extended right hepatectomy group ($n = 18$)	*P*-value
Sex (male/female)	30/7	13/5	0.50
Age (years)	28.8 ± 9.1	32.7 ± 11.9	0.30
Pre-operative body weight (kg)	65.5 ± 8.5	64.6 ± 7.6	0.99
Pre-operative steatosis	22/37	12/18	0.42
Mean pre-operative macrovesicular steatosis (%, range)	5.8 ± 7.6(0–30)	4.4 ± 4.8(0–20)	0.92
Remnant liver volume (%)	38.6 ± 2.8	37.1 ± 3.0	0.09

Macroscopic steatosis was observed in 22 out of 37 donors in RH group and 12 out of 18 MERH group at the time of operation. Ratio with steatosis was not different in both groups (Table 1). In RH group, 13 donors showed macrovesicular steatosis ≤5%. Five donors showed macrovesicular steatosis more than 5% and ≤15%. In four donors, macrovesicular steatosis was more than 15%. In MERH group, 10 donors showed macrovesicular steatosis ≤5%. Two donors showed macrovesicular steatosis 10% and 20% each, and these two donors received donor hepatectomy in an earlier period of our liver transplantation program.

We investigated and compared retrospectively the clinical outcomes of both groups. Also, we measured the remnant liver volume 4 months after operation in donors, and calculated 4 months liver regeneration index as follows; 4-month regeneration index (%) = (liver volume at POD 120/pre-operative remnant liver volume) $\times$ 100. This value was compared between the two groups.

Postoperative complications of both groups were compared.

In our institution, we performed complication surveillance in donors prospectively in all donors [11]. We defined hyperbilirubinemia when a serum total bilirubin (TB) was >3.0 mg/dl postoperatively or >1.3 mg/dl 7 days after hepatectomy. Biliary leakage was defined when total drain bilirubin exceeded that of serum 7 days after donor hepatectomy. Ileus was defined as requiring re-admission after discharge or re-operation. Pleural effusion was detected by chest X ray or computed tomography (CT). Wound problem included wound infection, delayed stitch-out or keloid formation. Asymptomatic intra-abdominal fluid collection was found by CT, and prolonged ascites were defined when a postoperative drain was required to be left in place for more than 10 days.

Statistical analyses were performed by using SPSS for WINDOW version 11.5 (SPSS Korea, Seoul, South Korea). We compared between groups with chi-squared test and nonparametric analysis. Statistical significance was defined when P-value was <0.05.

Results

There was no operative mortality or re-operation in both groups. Operation time was 297.0 ± 50.0 min in RH group and 290.8 ± 53.0 min in MERH group ($P > 0.05$). Intra-operative blood loss was similar in both groups (426.5 ± 217.3 ml in RH group vs. 453.3 ± 190.0 ml in MERH group, $P > 0.05$). There were no differences in serum AST, ALT, and TB levels at 30 days after operation (28.8 ± 10.5 IU/l, 43.7 ± 45.0 IU/l, and 0.98 ± 0.30 mg/dl in RH group vs. 32.5 ± 15.2 IU/l, 34.5 ± 22.9 IU/l, and 0.86 ± 0.43 mg/dl in MERH group, respectively, $P > 0.05$). The volume of fluid drainage from the abdominal cavity was larger in MERH group at POD3 (105.9 ± 80.7 ml in RH group vs. 295.5 ± 139.9 ml in MERH group, $P < 0.01$) and POD5 (105.9 ± 111.1 ml in RH group vs. 224.6 ± 139.6 ml in MERH group, $P = 0.002$).

Duration of postoperative hospital stay was not different between two groups (12.8 ± 3.7 days in RH group vs. 12.5 ± 2.9 days in MERH group, $P = 0.94$). The liver regeneration indices at 4 months after operation were 200.0 ± 35.7% in RH group and 209.8 ± 35.7% in MERH group. These were statistically not different (Table 2).

Table 2. Postoperative course.

	Right hepatectomy group ($n = 37$)	Modified extended right hepatectomy group ($n = 18$)	P-value
Operation time (min)	297.0 ± 50.0	290.8 ± 53.0	0.62
Intra-operative blood loss (ml)	426.5 ± 217.3	453.3 ± 190.0	0.38
AST POD30 (IU/l)	28.8 ± 10.5	32.5 ± 15.2	0.55
ALT POD30 (IU/l)	43.7 ± 45.0	34.5 ± 22.9	0.57
Total bilirubin POD30 (mg/dL)	0.98 ± 0.30	0.86 ± 0.43	0.10
Postoperative drainage at POD 3	105.9 ± 80.7	295.5 ± 139.9	<0.001
Postoperative drainage at POD 5	105.9 ± 111.1	224.6 ± 139.6	0.002
Day of drain removal (days)	9.4 ± 3.5	12.5 ± 7.6	0.10
Postoperative hospital stay (days)	12.8 ± 3.7	12.5 ± 2.9	0.94
Four-month regeneration index* (%)	200.0 ± 35.7	209.8 ± 35.7	0.28

Four-month regeneration index* (%) = (liver volume at POD 120/pre-operative remnant liver volume) × 100.

Table 3. Comparison of complications.

	Right hepatectomy group ($n = 37$)	Modified extended right hepatectomy group ($n = 18$)	P-value
Complication rate (n, %)	23 (62.2%)	11 (61.1%)	0.58
Complications (cumulative number)			
Hyperbilirubinemia	13	4	0.05
Fluid collection	5	5	
Bile leak	6	3	
Ascites	1	2	
Ileus	0	2	
Bleeding	1	1	
Pleural effusion	5	0	
Wound problem	3	0	
Others	6	1	

Postoperative complications of both groups are listed in Table 3. Overall complication rate was 62.2% in RH group and 61.1% in MERH group, and there was no statistical difference ($P = 0.58$). In RH group, hyperbilirubinemia occurred in 13 donors, fluid collection in peritoneal cavity occurred in five, bile leak in six, ascites in one, pleural effusion in five, wound problem in three, and minor bleeding in one. In MERH group, hyperbilirubinemia occurred in four, fluid collection in peritoneal cavity in five, bile leak in three, ascites in two, postoperative ileus in two, minor bleeding in one. There was no statistical difference in the rates of individual complications. All patients with complications recovered without residual disabilities, and persistent medical treatment was not necessary in all patients.

Discussion

In adult-to-adult LDLT, the major limitation is the adequacy of the graft size [2]. LDLT using left liver graft resulted in a poor post-transplant survival rate, when the graft was <1.0% of the recipient's body weight [12]. To meet metabolic demand of adult recipient and to improve the survival rate, right liver graft has been introduced [13,14].

A right liver graft may be problematic when complicated with severe congestion of the right anterior sector. Lee *et al.* [4] reported that severe right anterior sector congestion results in complications and poor patient survival, and suggested that preservation and reconstruction of the MHV tributaries. Sano *et al.* [15] suggested that intra-operative Doppler ultrasonography with vessel clamping was a useful indicator when deciding whether to reconstruct MHV tributaries. Variable methods for reconstruction of MHV tributaries were introduced. Some authors use autogenous vein grafts for interposition harvested from the recipients, donors or cadavers [6,16]. Sugawara *et al.* [6] used cryopreserved veins such as iliac vein or the vena cava to reconstruct MHV tributaries. Hwang *et al.* [17] reported reconstruction of MHV tributaries of the anterior segment using autologous great saphenous vein, cryopreserved iliac vein and artery. But, reconstruction of MHV tributaries with jump grafts would be a more complex, and require long-operation time [18].

In addition, extended RH including MHV was first introduced by Hong Kong group. In these procedures, a small part of Sg4 was used to be included in graft liver [7,9]. In MERH of our center, the entire parenchyme of segment 4 is not resected and remained, and only MHV is harvested to donor right graft [10]. We previously reported that whole remnant donor liver regeneration was not different from conventional RH donors at 4 months after operation.

It is well known that RH in live liver donation, even without MHV harvest, had considerable morbidity rates compared to left hepatectomies or left lateral sectionectomies [19,20]. Moreover, MHV harvesting with right liver graft can have adverse effect on the donor. Donor safety is the most important in planning the MHV harvest. Scatton *et al.* [21] reported that RH with MHV never affects morbidity or impairs early liver function and regeneration in donors. Villa *et al.* [18] suggested that if the graft were small in size and remnant liver volume adequate, right lobe graft could be taken with or without the MHV with equally successful outcomes in donors.

In our series, postoperative complications were not different in donors who received MERH and RH. Postoperative liver functions were not different too. But, postoperative drain amount was larger in MERH donors, and drain removal tended to be delayed in MERH group. This finding is probably because of temporary disturbance of hepatic venous drainage and transient portal hypertension in MERH group because of absence of MHV [22–24]. But, no patient in MERH group required diuretic therapy after operation for ascites control, and no clinical sequelae were observed in either groups. Day of discharge after operations was similar in both groups, and there were no persistent problems of portal hypertension with persistent ascites.

Yokoi *et al.* [25] suggested that even mild steatosis of the liver could be a risk factor for RH from living donors. So, we do not perform MERH if hepatic steatosis is present in frozen biopsy. In an earlier period of our program, two donors with hepatic steatosis underwent MERH. These donors suffered complications such as hyperbilrubinemia and prolonged ascites drainage. After this, we perform frozen biopsy to check steatosis of liver, and do not perform MERH if macroscopic steatosis exceeds 5%.

Our results show that MERH did not impair recovery or liver regeneration in donors, and indicate that MERH can be carried out safely in adult LDLT when the remnant liver exceeds 35% without steatosis.

Authorship

E-HC performed study, collected and analyzed data, and wrote the paper. K-SS designed and performed study, collected and analyzed the data. HWL, WYS, N-JY and KUL performed study and collected the data.

References

1. Chen CL, Fan ST, Lee SG, *et al.* Living-donor liver transplantation: 12 years of experience in Asia. *Transplantation* 2003; **75**(Suppl.): S6.
2. Suh KS, Kim SH, Kim SB, *et al.* Safety of right lobectomy in living donor liver transplantation. *Liver Transpl* 2002; **8**: 910.
3. Maetani Y, Itoh K, Egawa H, *et al.* Factors influencing liver regeneration following living-donor liver transplantation of the right hepatic lobe. *Transplantation* 2003; **75**: 97.
4. Lee SG, Park KM, Hwang S, *et al.* Congestion of right liver graft in living donor liver transplantation. *Transplantation* 2001; **71**: 812.
5. Inomata Y, Uemoto S, Asonuma K, *et al.* Right lobe graft in living donor liver transplantation. *Transplantation* 2000; **69**: 258.
6. Sugawara Y, Makuuchi M, Sano K, *et al.* Vein reconstruction in modified right liver graft for living donor liver transplantation. *Ann Surg* 2003; **237**: 180.
7. Lo CM, Fan ST, Liu CL, *et al.* Adult-to-adult living donor liver transplantation using extended right lobe grafts. *Ann Surg* 1997; **226**: 261.
8. Fan ST, Lo CM, Liu CL. Technical refinement in adult-to-adult living donor liver transplantation using right lobe graft. *Ann Surg* 2000; **231**: 126.
9. Lo CM, Fan ST, Liu CL, Wong J. Hepatic venoplasty in living donor liver transplantation using right lobe graft with middle hepatic vein. *Transplantation* 2003; **75**: 358.
10. Suh KS, Yi NJ, Cho JY, Kwon CH, Minn KW, Lee KU. Technical refinement preserving segment 4 to donor in extended right hepatectomy. *Hepatogastroenterol* 2006; **53**: 253.
11. Cho JY, Suh KS, Kwon CH, *et al.* Outcome of donors with a remnant liver volume of less than 35% after right hepatectomy. *Liver Transpl* 2006; **12**: 201.
12. Kiuchi T, Kasahara M, Uryuhara K, *et al.* Impact of graft size mismatching on graft prognosis in liver transplantation from living donors. *Transplantation* 1999; **67**: 321.

13. Itamoto T, Emoto K, Mitsuta H, *et al.* Safety of donor right hepatectomy for adult-to-adult living donor liver transplantation. *Transpl Int* 2006; **19**: 177.
14. Marcos A, Ham JM, Fisher RA, Olzinski AT, Posner MP. Single-center analysis of the first 40 adult-to-adult living donor liver transplants using the right lobe. *Liver Transpl* 2000; **6**: 296.
15. Sano K, Makuuchi M, Miki K, *et al.* Evaluation of hepatic venous congestion: proposed indication criteria for hepatic vein reconstruction. *Ann Surg* 2002; **236**: 241.
16. Fan ST, Viilla VH, Kiuchi T, Lee SG, Makuuchi M. Right anterior sector drainage in right-lobe live-donor liver transplantation. *Transplantation* 2003; **75**: S25.
17. Hwang S, Lee SG, Ahn CS, *et al.* Cryopreserved iliac artery is indispensable interposition graft material for middle hepatic vein reconstruction of right liver grafts. *Liver Transpl* 2005; **11**: 644.
18. de Villa VH, Chen CL, Chen YS, *et al.* Right lobe living donor liver transplantation – addressing the middle hepatic vein controversy. *Ann Surg* 2003; **238**: 275.
19. Miyagi S, Kawagishi N, Fujimori K, *et al.* Risks of donation and quality of donors' life after living donor liver transplantation. *Transpl Int* 2004; **18**: 47.
20. Choi SJ, Gwak MS, Kim MH, *et al.* Differences of perioperative liver function, transfusion, and complications according to the type of hepatectomy in living donors. *Transpl Int* 2005; **18**: 548.
21. Scatton O, Belghiti J, Dondero F, *et al.* Harvesting the middle hepatic vein with a right hepatectomy does not increase the risk for the donor. *Liver Transpl* 2004; **10**: 71.
22. Benzoni E, Cojutti A, Lorenzin D, *et al.* Liver resective surgery: a multivariate analysis of postoperative outcome and complication. *Langenbecks Arch Surg* 2007; **392**: 45.
23. Nagasue N. Liver resection for hepatocellular carcinoma: indications, techniques, complications, and prognostic factors. *J Hepatobiliary Pancreat Surg* 1998; **5**: 7.
24. Nagasue N, Yukaya H, Ogawa Y, Higashi T. Portal pressure following partial to extensive hepatic resection in patients with and without cirrhosis of the liver. *Ann Chir Gynaecol* 1983; **72**: 18.
25. Yokio H, Isaji S, Yamagiwa K, *et al.* Donor outcome and liver regeneration after right-lobe graft donation. *Transpl Int* 2005; **18**: 915.

