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ORIGINAL ARTICLE

Differences of perioperative liver function, transfusion, and complications according to the type of hepatectomy in living donors

Soo Joo Choi, Mi Sook Gwak, Myung Hee Kim, Mikyung Yang, Justin Sang Ko, Tae Soo Hahm and Gaab Soo Kim

Department of Anesthesiology and Pain Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine, Seoul, Korea

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Correspondence
Mi Sook Gwak MD, Department of Anesthesiology and Pain Medicine, Samsung Medical Center, Sungkyunkwan University School of Medicine, 50 Ilwon-dong, Kangnam-ku, Seoul 135-710, Korea.
Tel.: 82-2-3410-0359; fax: 82-2-3410-0361;
e-mail: gwakms@smc.samsung.co.kr

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Summary

Numerous living donor hepatectomy are being performed safely. However, donors are still exposed to various complications including hepatic failure. We examined the donor's potential risk and morbidity depending on the type of hepatectomy: left lateral segmentectomy (group LLS, $n = 30$), left lobectomy (group LL, $n = 15$), and right lobectomy (group RL, $n = 128$). The charts and computerized hospital data of 173 donors from March 2000 to September 2003 were retrospectively reviewed. We analyzed liver function tests (LFT), RBC transfusion, and complications. Although the graft weight was greatest, and surgical and anesthetic times were longest in the group RL, there were no significant differences in postoperative hospital stay, RBC transfusion, and major complications among the groups. However, minor complications were significantly higher in group RL than group LLS. Postoperative prothrombin time and total bilirubin were significantly higher in the group RL than the other groups ($P < 0.05$). Living donor hepatectomy is relatively safe, and it is evidenced by rapid recovery of LFT and low occurrence of major complications. However, noticeable depression of LFT and frequent minor complications occur after hepatectomy, especially RL.

Introduction

The first donor operation for living-related liver transplantation (LRLT) began when adult left lateral segment was transplanted in a child recipient [1]. This successful adult–child LRLT led to adult–adult LRLT along with concurrent improvements in surgical techniques and patient management. At the early stage of adult–adult LRLT, left lobectomy (LL) was performed predominantly with regard to donor's safety, but, in many cases, left lobe was determined insufficient for the recipient. Then, right lobe was first used in adult–adult LRLT in 1994, and at present, right lobe transplantation is being performed in great numbers [2].

In our hospital, liver transplantation (LT) began with cadaveric liver in May 1996, soon followed by adult–child LRLT in June, same year, and then, the 300th LT was performed in October 2003. In South Korea, organ transplant law was enacted on February 9, 2000, and brain death was legalized for the purpose of organ transplantation. Korean Network for Organ Sharing (KONOS) was launched for fair and effective management of organ transplantation. After the enactment of organ transplant law, organs from the brain deaths were not available to any one specific medical center, but rather, equally distributed nation-wide via KONOS. This led to the severer shortage of cadaveric donors in our hospital. Before the organ transplant law, majority of LT was comprised of cadaver LT and adult–child LRLT with only two cases of adult–adult LRLT. However, after the enactment of the law, most liver transplantation is adult–adult LRLT, using mostly right lobe.

It is a general consensus that LRLT is considered as a relatively safe and useful procedure evidenced by excellent outcomes. However, donors might be exposed to various potential complications of preoperative laboratory examinations, operation and anesthesia, and although rare, to sustained hepatic dysfunction or hepatic failure after hepatectomy. The outcome of adult–adult LRLT has been improved by the use of right lobe providing larger volume than left lobe [3]. Donor's right lobe provides sufficient liver mass to the recipient. However, in donor's perspective, the remnant liver mass is substantially smaller in right lobe donors than left lateral segment and left lobe donors. Soejima *et al.* [4] mentioned that the more hepatic mass removed from the donor, the greater the chance of liver failure after hepatectomy. There were several reports that morbidity was greater among right lobe donors than left lobe donors [5,6]. Surman [7] reported that two donors had to undergo LT themselves after donating the right lobe.

Thus, the purpose of this study is to assess living donor's potential risk and morbidity depending on the type of hepatectomy, and to determine if these risk and morbidity were higher in right lobe donors.

Materials and methods

We reviewed a total of 173 consecutive donors who had undergone donor hepatectomy for LRLT from March 2000 to September 2003 at Samsung Medical Center, Seoul, Korea. After approval by the hospital Ethical Committee, donor's data including anesthesia records, operation records, and ICU records, and the computerized hospital data were reviewed, retrospectively.

The 173 donors included 114 males and 59 females. Their mean age, body weight, and height were 32.9 ± 9.2 years, 64.7 ± 9.6 kg, and 167.0 ± 7.5 cm respectively. All donors were American Society of Anesthesiologists (ASA) physical status I ($n = 168$) or II ($n = 5$). The ASA II donors had systemic diseases, such as diabetes mellitus, IgA nephropathy, hypertension, or mild mitral regurgitation combined with atrial septal defect, but none showed functional limitations. Preoperative surveillance for donors included hematology (complete blood count, serum electrolytes, blood type, HLA type), biochemical liver, renal, standard coagulation tests, viral serology, urine analysis, and stool examination for occult blood. In addition, electrocardiogram (ECG), chest X-ray, abdominal supine/erect X-ray, pulmonary function test (over 40 years only), abdominal ultrasonography, computed tomography, and angiography were routinely performed. Liver biopsy was performed when greater than mild fatty change was shown on ultrasonography. A total of 23 donors (six in the group LLS, two in the group LL, and 15 in the group RL) underwent preoperative liver biopsies. Acceptance criteria for donors were as follows: ages between 16–60 years old, not HBsAg carriers, ABO blood type identical or compatible, lab values within normal limits, fatty liver change on ultrasonography normal or mild, or steatosis at liver biopsy <30%, residual liver volume of donor greater than 35%, and graft weight/body weight of recipient greater than 0.8 or graft volume/standard liver volume of recipient greater than 40%. We obtained the informed consent from the donors, and then all donors received counseling from psychologist and social worker before the planned operation. Donors were arranged for preoperative autologous blood donation of 1–2 units at least 3 days before the operation (1 week apart between blood donations) when the patient desired and hemoglobin (Hb) level was >10 g/dl.

Donor operations were classified into three groups as follows: left lateral segmentectomy (group LLS, $n = 30$), left lobectomy (group LL, $n = 15$), and right lobectomy (group RL, $n = 128$). Graft weight, surgical and anesthetic times, administered fluids, estimated blood loss, duration of postoperative hospital stay, RBC transfusion, and complications were investigated. Aspartate aminotransferase (AST), alanine aminotransferase (ALT), prothrombin time (PT), total bilirubin (TB) and Hb were analyzed at preoperative period, immediately after operation, and on the first, second, third, fifth, seventh and 30th postoperative day (POD).

Anesthesia monitoring included ECG, intraarterial (via radial artery catheter) and central (via an internal jugular catheter) pressure monitoring, pulse oxymetry, capnography, urine output, neuromuscular blockade, and esophageal core temperature. Anesthesia was induced with thiopental (5 mg/kg), vecuronium (0.15 mg/kg) and fentanyl (2 μg/kg), and was maintained with isoflurane (end-tidal concentration 1–2 vol%) in a 50% oxygen-medical air balance. Additional fentanyl and vecuronium were administered as appropriate. Intraoperative normothermia was maintained by means of a warm blanket, humidifier, warm intravenous fluids, and a forced air-warming system (Bair Hugger®; Augustine Medical Inc., Eden Prairie, MN, USA). After operation, all donors were transferred to ICU for close monitoring and further management. Perioperative RBC transfusion was initiated when Hb level was <9 g/dl in case of autologous blood transfusion and <8 g/dl in homologous blood transfusion. Postoperative analgesia was provided by intravenous or epidural patient-controlled analgesia (PCA) according to the donor's preoperative wishes and medical history.

The statistical program used in this study was SPSS 11.0 for Windows (SPSS Inc., Chicago, IL, USA) and data are presented as numbers or mean ± SD. For continuous data, overall differences were tested by one-way ANOVA,

followed by Tukey's multiple comparisons test for further comparisons. For categorical data, significance of differences was determined by chi-square or Fisher's exact test. The difference was regarded as statistically significant when the $P < 0.05$.

Results

There were no significant differences in demographic data (Table 1) and the preoperative liver function tests (LFT) among the three groups (Fig. 1).

The graft weight was significantly greater, the remnant liver volume was significantly smaller, and surgical and anesthetic times were significantly longer in group RL than those in the other two groups ($P < 0.01$). Significantly more crystalloid and colloid were administered during anesthesia in group RL than group LLS ($P < 0.05$), but not for group LL. There were no significant differences in the estimated blood loss and postoperative hospital stay among the three groups (Table 2).

Serial changes in the perioperative serum levels of AST, ALT, PT, and TB are shown in Fig. 1. Mean values of these parameters reached a maximum on the first or second POD. On the seventh POD, the serum AST and ALT values showed no differences among the three groups, whereas the serum PT and TB values in the groups RL were still significantly higher than the group LLS ($P < 0.01$). On the 30th POD, all these parameters showed no significant differences among the three groups.

During intra- and postoperative period, 30 of 173 donors (17.3%, four donors in group LLS, one donor in group LL, and 25 donors in group RL) received whole or packed RBC transfusion, and among them, eight donors (4.6% of all donors, one donor in group LLS and seven donors in group RL) received homologous blood transfusion. In all donors who received 1 unit, only autologous blood was used. There were no significant differences in the frequency of RBC transfusion and perioperative Hb values among the three groups (Table 3; Fig. 2).

Overall, 103 of 173 donors (59.5%) did not experience any complications. Postoperative complications are listed in Table 4. There was no significant difference in number of donors who experienced complications among the groups. Major complications in group RL were not significantly different from those in the other two groups, but minor complications were significantly higher in group RL than group LLS ($P < 0.05$). The three most frequent complications were pleural effusion, hyperbilirubinemia, and atelectasis. The overall incidences of those complications were 17.3% 15.6%, and 12.1% respectively. Numbers of donors who experienced two complications simultaneously were three in group LLS, two in group LL, and 13 in the group RL. Numbers of donors who experienced three and four complications simultaneously were three and one, respectively, in group RL. Reoperation related to hepatectomy was performed in six donors (0.03%). One was operated for ileus because of adhesion between duodenum and cut surface of liver in the group RL, another for postoperative bleeding in the same group, four were operated for wound dehiscence (three in group RL, one in group LL). There were no pneumothorax or hemothorax because of central venous catheter insertion, epidural abscess or hematoma caused by epidural catheter insertion for PCA, renal failure, sustained hepatic dysfunction or hepatic failure, thromboembolism, sepsis, and death in all donors.

Table 1. Demographic data.

	Group LLS ($n = 30$)	Group LL ($n = 15$)	Group RL ($n = 128$)
Age (years)	30.4 ± 4.4	34.1 ± 8.6	33.4 ± 10.0
Sex (M/F)	20 (66.7%)/10 (33.3%)	9 (60.0%)/6 (40.0%)	85 (66.4%)/43 (33.6%)
Body weight (kg)	62.7 ± 8.7	63.0 ± 10.7	65.4 ± 9.7
Height (cm)	167.2 ± 7.8	165.4 ± 6.9	167.9 ± 7.6
ASA status (I/II)	29 (96.7%)/1 (3.3%)	15 (100%)/0 (0%)	124 (96.9%)/4 (3.1%)
Blood type (A/B/AB/O)	8/11/0/11 (26.7%/36.7%/0/36.7%)	1/7/0/7 (6.7%/46.7%/0%/46.7%)	38/28/1/61 (29.7%/21.9%/0.8%/47.7%)
Relationship with recipient			
Parent (father/mother)	27 (90%, 18/9)	7 (46.7%, 2/5)	5 (3.9%, 2/3)
Sibling (brother/sister)	1 (3.3%, 1/0)	2 (13.3%, 2/0)	25 (19.5%, 20/5)
Spouse (husband/wife)	0 (0%, 0/0)	1 (6.7%, 0/1)	21 (16.4%, 4/17)
Child (son/daughter)	0 (0%, 0/0)	2 (13.3%, 2/0)	39 (30.5%, 27/12)
Relative (M/F)	1 (3.3%, 0/1)	2 (13.3%, 2/0)	21 (16.4%, 17/4)
Non-relative (M/F)	1 (3.3%, 1/0)	1 (6.7%, 1/0)	17 (13.3%, 15/2)

Values are expressed as mean ± SD or numbers of donors.
LLS, left lateral segmentectomy; LL, left lobectomy; RL, right lobectomy; ASA, American Society of Anesthesiologists.
There were no significant differences in age, sex, body weight, and height among the groups.

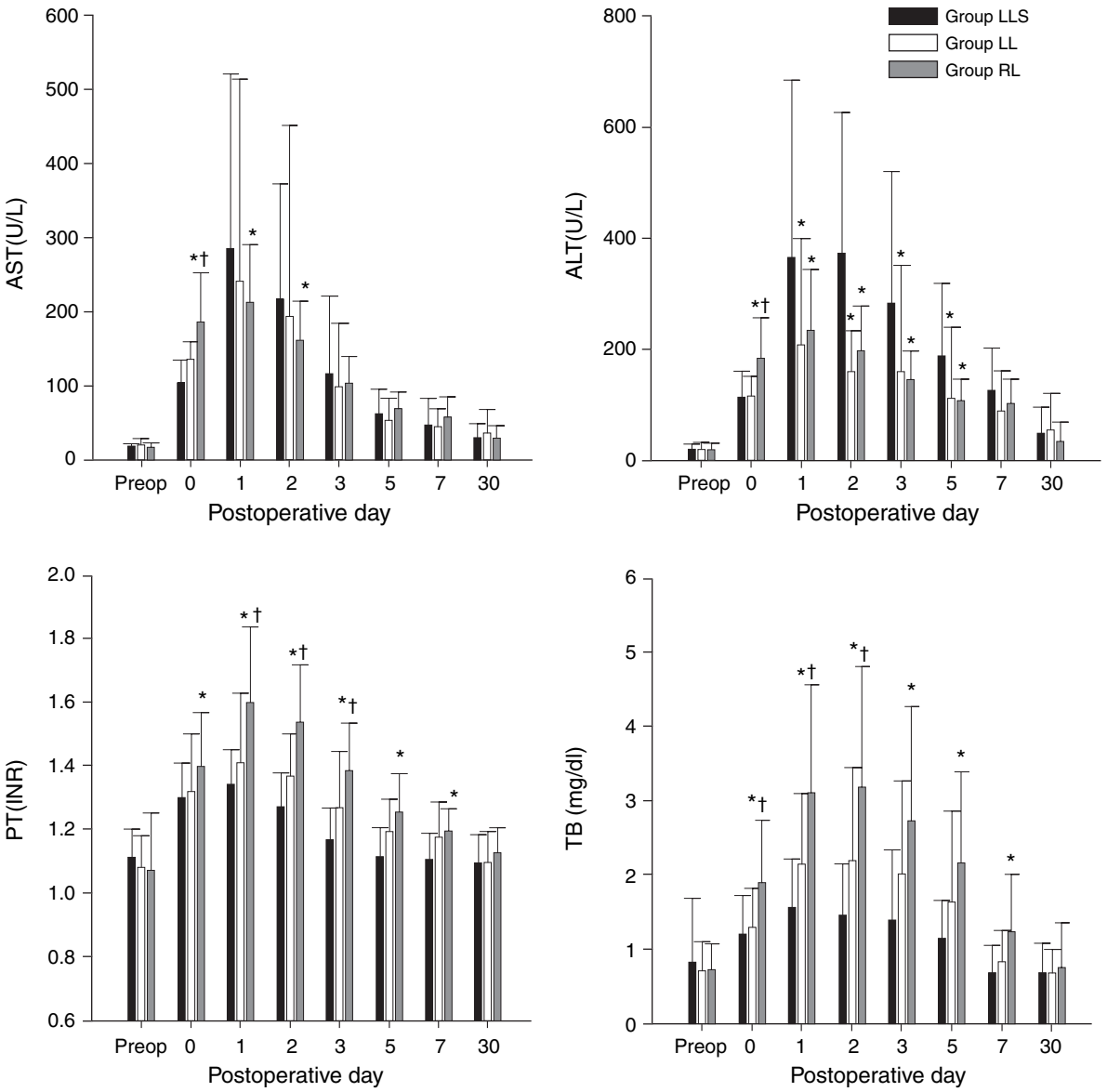

Figure 1 Serial changes in perioperative aspartate aminotransferase (AST), alanine aminotransferase (ALT), prothrombin time (PT), and total bilirubin (TB). Values are expressed as mean ± SD. LLS, left lateral segmentectomy; LL, left lobectomy; RL, right lobectomy. *$P < 0.05$ versus group LLS, †$P < 0.05$ versus group LL.

Overall recipient and graft survival rates at 1 year were 84.4% and 82.7%, respectively. The recipient and graft survival rates at 1 year were 96.7% and 93.3% in group LLS, 66.7% and 66.7% in group LL, and 85.6% and 82.0% in group RL, respectively.

Discussion

The major findings of this study were that the changes of the perioperative PT and TB were greatest and minor complications were most frequent in the RL. This suggests that potential risk in immediate postoperative period is highest in RL. However, any three types of donor hepatectomy were relatively safe as witnessed by rapid recovery of LFT and low rates of perioperative homologous blood transfusion and major complications.

Other studies have reported different findings from our results on postoperative LFT, blood loss and transfusion, and duration of hospital stay according to the type of donor hepatectomy [8–11]. Sugawara *et al.* [10] reported that although the longest surgical time and the greatest blood loss were observed in LL compared with LSS and

Table 2. Surgical and anesthetic data.

	Group LLS ($n = 30$)	Group LL ($n = 15$)	Group RL ($n = 128$)
Graft weight (g)	246.9 ± 42.9	433.4 ± 158.7*	713.9 ± 142.0*†
GV/SLV (%)	76.3 ± 38.8	50.7 ± 20.9*	66.5 ± 21.4
TLV (ml)	1226.0 ± 200.3	1191.6 ± 250.7	1253.8 ± 207.1
RLV (%)	80.7 ± 12.5	62.1 ± 8.3*	43.2 ± 8.0*†
Surgical time (min)	365.8 ± 51.0	381.6 ± 62.8	443.0 ± 64.9*†
Anesthetic time (min)	404.0 ± 49.7	412.3 ± 58.2	486.7 ± 68.3*†
Crystalloid (ml)	3110.0 ± 846.6	3293.3 ± 1105.6	3696.8 ± 933.7*
Colloid (ml)	330.0 ± 238.0	400.0 ± 280.3	471.8 ± 275.7*
Estimated blood loss (ml)	573.9 ± 320.6	711.5 ± 256.7	705.7 ± 350.3
Urine output (ml)	663.1 ± 279.4	698.6 ± 296.2	855.8 ± 464.9
Postoperative hospital stay (days)	10.0 ± 1.6	11.4 ± 2.2	12.2 ± 5.2

Values are expressed as mean ± SD.
GV, graft volume; SLV, standard liver volume of recipient = 706.2 × body surface area (m^2) + 2.4; TLV, total liver volume of donor; RLV, remnant liver volume of donor, ([TLV–GV]/TLV) × 100; LLS, left lateral segmentectomy; LL, left lobectomy; RL, right lobectomy.
*$P < 0.05$ compared with group LLS.
†$P < 0.05$ compared with group LL.

Table 3. Whole blood or packed red blood cells transfusions.

	Group LLS ($n = 30$) (%)	Group LL ($n = 15$) (%)	Group RL ($n = 128$) (%)
Total	4 (13.3)	1 (6.6)	25 (19.5)
Intraoperative	3 (10.0)	0	20 (15.6)
1 unit	2 (6.6)	0	16 (12.5)
2 units	1 (3.3)	0	3 (2.3)
3 units	0	0	1 (0.8)
Postoperative	1 (3.3)	1 (6.6)	5 (3.9)
1 unit	1 (3.3)	0	1 (0.8)
2 units	0	1 (6.6)	4 (3.1)

Values are expressed as number of donors.
LLS, left lateral segmentectomy; LL, left lobectomy; RL, right lobectomy.
There was no significant difference in total number of RBC transfusion among the groups.

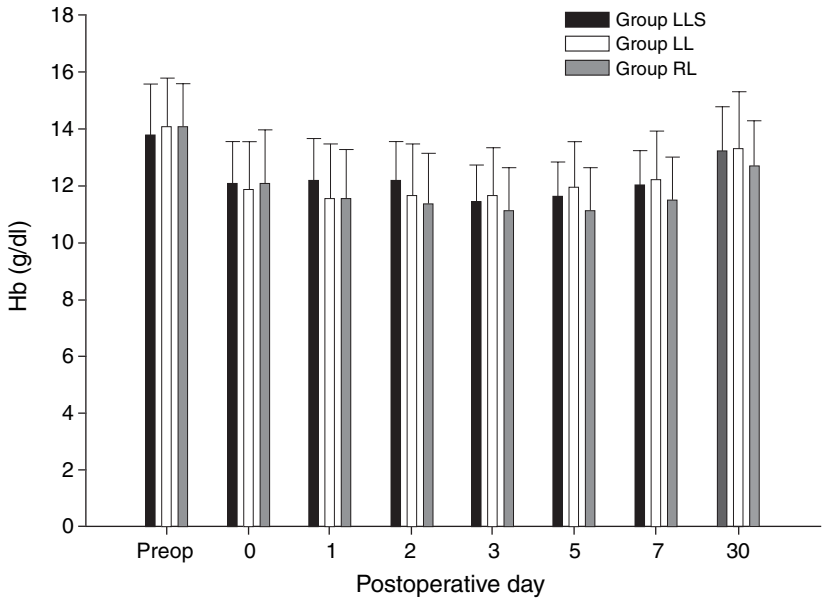

Figure 2 Serial changes in perioperative hemoglobin (Hb). Values are expressed as mean ± SD. LLS, left lateral segmentectomy; LL, left lobectomy; RL, right lobectomy. There was no significant difference among the groups.

Table 4. Postoperative complications.

Complications	Group LLS ($n = 30$) (%)	Group LL ($n = 15$) (%)	Group RL ($n = 128$) (%)
No. of donors experienced complications	7 (23.3)	6 (40.0)	57 (44.5)
Overall complications	11 (36.7)	7 (46.7)	85 (66.4)*
Major complications	0	1 (6.7)	6 (4.7)
Bile duct stenosis	0	1 (6.7)	2 (1.6)
Severe hypotension and bradycardia at ICU	0	0	1 (0.8)
Ileus caused by adhesion (reoperation)	0	0	1 (0.8)
Intra-abdominal bleeding (reoperation)	0	0	1 (0.8)
Fluid collection at perihepatic area	0	0	1 (0.8)
Minor complications	11 (36.7)	6 (40.0)	79 (61.7)*
Atelectasis	5 (16.7)	2 (13.3)	14 (10.9)
Pleural effusion	3 (10.0)	1 (6.7)	26 (20.3)
Mild pulmonary edema	1 (3.3)	0	0
Alopecia	0	0	1 (0.8)
Hand numbness	0	0	2 (1.6)
Hyperbilirubinemia (TB >5 mg/ml)	1 (3.3)	2 (13.3)	24 (18.7)
Wound infection or dehiscence	1 (3.3)	1 (6.7)	7 (5.5)
Gastric ulcer	0	0	1 (0.8)
Ischemic colitis	0	0	1 (0.8)
Postoperative delirium	0	0	1 (0.8)
Contact dermatitis	0	0	1 (0.8)
Irritable bowel syndrome	0	0	1 (0.8)

Values are expressed as number of donors.
LLS, left lateral segmentectomy; LL, left lobectomy; RL, right lobectomy; TB, total bilirubin.
*$P < 0.05$ compared with group LLS. Some donors had more than one complication.

RL, duration of postoperative hospital stay and blood transfusion units showed no differences among the three groups. Additionally, they reported that peak AST value was highest in LSS, and peak total bilirubin values were not significantly different among the groups. Similarly, in our study, peak values of AST and ALT were highest after LSS, and ALT value showed statistical significance. They pointed that higher AST and ALT values in LSS reflect the greater area of devascularized remnant liver after division of the left portal vein and left hepatic artery with division of the segment 4 artery [10]. Shimada *et al.* [11] reported that there were no differences in surgical time, blood loss, and postoperative ALT value between LR and RL, but there were higher AST and TB values as well as longer duration of hospital stay in RL. In Kanoh *et al.*'s [12] study of hepatocellular carcinoma, they observed no differences in surgical time and blood loss between LR and RL, whereas they observed more frequent blood transfusion and delayed recoveries of TB and clotting disorder in RL. In our study, AST, ALT, PT, and TB were significantly higher at the postoperative period in group RL than group LL. Both surgical and anesthetic times were significantly longer in group RL, but the duration of postoperative hospital stay was not different among the groups. When the changes in LFT were evaluated according to the time periods, all the measured parameters were at their highest levels on the first or second POD, and decreased rapidly afterwards in all three groups. TB and PT were significantly higher in group RL than the other two groups until the second or third POD, and still significantly higher than the group LLS on the seventh POD. Although there was no sustained hepatic dysfunction or hepatic failure even in group RL, the results suggest that the chance of this fatal complication during immediate postoperative period might be potentially higher in group RL than other two groups.

Umeshita *et al.* [5] previously reported that there was no difference in the frequency of homologous blood transfusion according to graft type. We also found no difference in the frequency of RBC transfusions in intra- and postoperative period among the three groups. Bak *et al.* [13] reported that homologous RBC transfusion was carried out in 5% of right lobe donors. Similarly, in our study, the frequency of homologous RBC transfusion in the group RL was 5.5%. Lutz *et al.* [14] suggested the donation of 3 units of autologous blood for donor's right hepatectomy in intraoperative period. In our hospital, intraoperative use of cell saver is not implemented in donor operation, and 30 of total 173 donors (17.3%) received packed or whole blood transfusion during either intra- or postoperative period [1 unit: 20 donors (11.6%), 2 units: nine donors (5.2%), 3 units: one donor (0.6%)], and no patients were transfused during intra- and postoperative periods sequentially. By this result, we can

suggest that when cell saver is not used intraoperatively, 2 units of preoperative autologous blood donation will be sufficient regardless of hepatectomy type during both intra- and postoperative periods.

In this study, various postoperative complications were noted in the group RL, but their incidences were very low, except for the atelectasis, pleural effusion and hyperbilirubinemia. Atelectasis, pleural effusion, and pulmonary edema were observed on chest X-ray, but there was no clinically noted respiratory distress. For the donor with fluid collection at perihepatic area, the fever of 38.5 °C was measured on the ninth POD, and abdominal ultrasonography was carried out. The fluid collection at posterosuperior aspect of RL site was detected. One hundred milliliter of dirty fluid was aspirated from the site and its bacterial culture revealed coagulase-negative staphylococcus. He was successfully treated with percutaneous drainage with 8.5Fr pig tail catheter and antibiotics treatment. For three donors with bile duct stenosis, two donors (one in group LL, one in group RL) were treated with percutaneous transhepatic biliary drainage and balloon dilatation, and remaining one donor in the group RL was treated with conservative treatment. Donors who experienced three or four complications simultaneously were only in group RL. Three donors had three complications simultaneously: one donor with wound problem, atelectasis, and pleural effusion, another donor with biliary stricture, atelectasis, and hyperbilirubinemia, and the other donor with gastric ulcer, pleural effusion, and hyperbilirubinemia. Only one donor had four complications simultaneously (atelectasis, pleural effusion, fluid collection at perihepatic area, and hyperbilirubinemia). Bak *et al.* [13] reported that large hemothorax secondary to preoperative central venous catheter placement occurred in one of 41 right lobe donors. Serious complications related to anesthesia were not observed in all the donors regardless of the type of hepatectomy in our study. However, in relation to patient's positions, alopecia and hand numbness were detected in group RL. Although the mechanisms are not clear, the occurrence of these complications in RL patients may be related to longer surgical and anesthetic times. Alopecia can be prevented by using soft pillow and by frequently rotating patient's head from side to side. Hand numbness was detected on the left arms in two patients and this might have been caused by constant compression of the left arm by nearby assistant operator or by overstretching of the arm. In addition, it may be prevented by placing both arms to the patient's sides. After the occurrence of second episode of hand numbness, above position was applied to all the donors and hand numbness was no longer observed in subsequent 117 donors. Therefore, when the patients are carefully monitored by giving special attention for any possible complications, then some of the complications can be prevented, even completely.

Umeshita *et al.* [5] reported that right lobe donors had more complications than left lateral segment and left lobe donors in the national survey. Fujita *et al.* [6] demonstrated that bile leakage is the most common complication after donor hepatectomy, especially after RL. Kanoh *et al.* [12] also reported that the incidence of all complications was significantly higher in RL than LL. Although there were no significant differences in the number of donors with complications and the incidence of major complications, the frequency of minor complications was higher in group RL. This suggests that greater care is needed in RL during the operation and anesthesia.

Brown *et al.* [15] reported that overall mortality was 0.2% and serious complications were 14% in survey of LRLT from living adult donors in the USA. Broelsch *et al.* [16] reported that 17.8% of donors experienced significant complications. In our study, the major complications were observed in 4%. Fortunately, there was no mortality in our hospital. There were several reports that some donors died from liver insufficiency [3], pulmonary embolism [17], aspiration pneumonia [7], or unclear cause [18]. Although the incidence of serious complications including hepatic failure and death is higher in RL, these serious complications can still occur in all types of hepatectomy. Therefore, close observation is required in all the donors.

In conclusion, we found that living donor hepatectomy, regardless of its type, showed rapid recovery of postoperative LFT with low incidences of homologous transfusion and serious complications. However, noticeable depression in LFT during the immediate postoperative period and various complications calls for vigilant patient monitoring, and additionally, careful pre-evaluation and selection of donors, especially in RL.

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