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ORIGINAL ARTICLE

Effect of Donor Right Hepatectomy on Splenic Volume and Platelet Count for Living Donor Liver Transplantation

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Abstract
Background Donor hepatectomy for living donor liver transplantation accompanies physio-morphological changes of the liver and spleen. Therefore, the long-term consequences of these organs should be characterized to ensure donor's safety.
Methods A total of 382 right liver harvests for liver transplantation were performed from October 2000 to February 2011. Clinical parameters across donor operations were compared, and the associations were investigated.
Results The remaining liver grew continually, reaching 81.5±11.2 % of the entire liver until 6 months after donation. The spleen grew to 143.1±28.8 % of the pre-donation value within 1 week after surgery, and thereafter, its size decreased gradually to 130.6±25.1 % at 6 months. At 6 months post-donation, 48.1 % (114/237) of donors showed an increase of ≥30 % in splenic volume, and 15.9 % (50/315) of donors exhibited a decrease of ≥30 % in platelet count. However, patients with splenic enlargement and/or decrease in platelet count at 6 months post-donation were not different in liver function, liver regeneration, or overall complications.
Conclusions Although splenic enlargement and/or decrease in platelet count can persist for more than 6 months after donation in patient population after donor right hepatectomy, such a change did not impact donor's safety.

Keywords Donor hepatectomy · Living donor liver transplantation · Thrombocytopenia · Liver regeneration · Splenic enlargement

Abbreviations

ALT	Alanine transaminase
AST	Aspartate transaminase
CT	Computed tomography
LDLT	Living donor liver transplantation
RLV	Remaining liver volume

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Introduction

Living donor liver transplantation (LDLT) has been proposed as an alternative to deceased donor liver transplantation to alleviate the donor organ shortage. Initially, the left lateral section of the liver was utilized as a graft for pediatric recipients, and thereafter, the left liver was used for adult recipients. Since the first report of LDLT using a right liver in 1994,[1] the right liver has become the most popular LDLT graft for adult patients. At the same time, a right hepatectomy for LDLT has caused controversy over donor's safety due to the smaller remaining liver volume (RLV) on the donor side and its possible related complications. Numerous investigators have research this topic, and most results supported the safety of living donors for LDLT using the right liver.[2–6] Such studies mainly paid attention to the outcomes after the donor operation in terms of morbidity and mortality. However, major hepatectomy inevitably results in altered portal pressure, and thereby, it was documented that splenic enlargement occurs during the postoperative period following major hepatic resection of diseased liver.[7] The postulation behind this phenomenon includes relative portal hypertension, causing splenic congestion and/or elevated levels of common growth

factors for the liver and spleen.[8,9] Nevertheless, clinical investigations concerning the morphological and functional changes in the liver and spleen are currently very limited, and their long-term effects have not been determined yet. Therefore, in this study, we investigated the long-term effects of donor hepatectomy in terms of physio-morphological consequences.

Patients and Methods

Study Design

A total of 382 consecutive donor right hepatectomies for LDLT were performed at the Department of Surgery, Seoul St. Mary's Hospital, The Catholic University of Korea, from October 2000 to February 2011. This study was approved by the Institutional Review Board of Seoul St. Mary's Hospital, The Catholic University of Korea. Of 382 adult living liver donors, 248 patients (64.9 %) were male, and the mean patient age was 32.9±10.9 years (range, 16–67 years). The mean body mass index was 23.4±2.8 kg/m^2 (range, 17.1–34.5 kg/m^2). Demographics, clinical data, and pathological data were collected and analyzed for all living liver donors before and after donation. The results of biochemical measurements and abdominal computed tomography (CT) with three-dimensional reconstruction were compared at pre-donation and at 1 week, 3 months, and 6 months after donation. Biochemical tests included serum levels of AST, alanine transaminase (ALT), total bilirubin, and platelet count. Abdominal CT volumetry was utilized to estimate RLV and splenic volume. The RLV calculation was made by summing the volumes using a workstation (EasyVision, Philips Medical Systems, Best, The Netherlands) to trace the outline of the liver on every image of the scan to calculate the area enclosed. Preoperative RLV was the volume of the left lobe compared to that of the whole liver on the preoperative CT evaluation. Splenic volume was determined by the equation: Volume = Length × Width × Thickness.[10] Length was determined by multiplying the number of sections in which the spleen was visualized by section thickness. Width was determined as the maximum width of the spleen, and thickness was measured at the midpoint where maximum thickness was obtained. Due to ethical reasons, we indirectly assumed alterations in portal hemodynamics by way of clinical parameters, such as liver regeneration, splenic enlargement, and platelet count. All donors underwent a liver biopsy during surgery. The degree of steatosis was evaluated by two expert pathologists. Only macrovesicular steatosis was estimated. All postoperative complications were classified according to their degree of severity and time of occurrence. The uniform reporting of adverse outcomes of surgery proposed by Clavien et al. was adopted to assess severity.[11]

Liver regeneration (in percent) at each period was calculated from estimated liver volume (cubic meter) at each period divided by immediate postoperative RLV (in cubic meter). Final liver regeneration (in percent) was calculated from the estimated liver volume (in cubic meter) at 6 months after surgery divided by preoperative whole liver volume (in cubic meter). Splenic size (in percent) at each period was calculated from the estimated splenic size (in cubic meter) at each period divided by preoperative splenic size, and platelet count (in percent) at each period was calculated from the platelet count (number per microliter) at each period divided by preoperative platelet count (number per microliter). When splenic volume at 6 months after donation increased to ≥30 % of the pre-donation value, we regarded it as sustained splenic enlargement. Sustained decrease in platelet count was defined when the platelet count at post-donation 6 months decreased to 30 % or more of that of the pre-donation value. We investigated the characteristics of patients with sustained splenic enlargement and/or decrease in platelet count in terms of postoperative complications and donor's safety. The median follow-up time was 73 months (range, 9–134 months).

Surgical Technique

A detailed description of the donor hepatectomy was provided previously.[12] Briefly, the abdomen was entered through a right subcostal incision. After a thorough examination of liver morphology, size, and consistency, a liver biopsy was performed at the liver border on the presumptive transection line. Full mobilization of the right liver was attempted after cholecystectomy and intraoperative cholangiography through the cystic duct stump. The falciform and right triangular ligaments were divided by electrocautery, and then full mobilization of the right liver was attempted. Next, we identified and dissected the portal triad, including the hepatic artery, portal vein, and the bile duct entering the right liver. The parenchymal transection plane was made along the demarcation line, which was noted after transient occlusion of the right hepatic artery and right portal vein. Parenchymal transection was then carried out using the Cavitron ultrasonic aspirator (CUSA, Valleylab, Boulder, CO, USA). The division of the caudate lobe was followed alongside the liver transection line. Ligation, division, and closure of the right branches of the hepatic duct, hepatic artery, portal vein, and hepatic vein were completed. After complete hepatic resection, a drain was inserted into the right subphrenic space.

Postoperative Care

All patients were treated with a standardized postoperative protocol. Daily laboratory tests were taken for seven

sequential days after the operation. A follow-up abdominal CT volumetry scan was taken at 1 week post-donation to evaluate remnant liver status, including vascular patency and regeneration. The operatively installed Jackson–Pratt drain was removed if the volume of discharge was ≤100 mL/day and did not contain bile juice at least after postoperative day 5. The decision to discharge the patient from the hospital was made 1 week after donation, based on the patient's condition and clinical parameters including imaging studies. All patients were regularly followed up in the outpatient clinic with regular surveillance for the liver and spleen by serial biochemical parameters and abdominal CT volumetry at 3 and 6 months post-donation.

Statistical Analysis

Numeric data are presented as means and standard deviations. Continuous variables were analyzed using the independent *t* test, Wilcoxon rank-sum test, or Kruskal–Wallis test, as appropriate. Proportions were compared using Pearson's chi-square test or Fisher's exact test, as appropriate. All *P* values were two-tailed. The statistical analysis was performed using SPSS ver. 15.0 (SPSS, Inc., Chicago, IL, USA). Statistical significance was accepted for *P* values of <0.05.

Results

Changes in Parameters Reflecting Portal Hemodynamic Alterations Across Donor Operations

Clinical parameters related to hepatic function and portal hemodynamic alterations were compared across donor right hepatectomies (Table 1) (Fig. 1). Serum levels of ALT and total bilirubin showed a similar pattern; after reaching their highest levels 1–2 days after the operation, they were remarkably stabilized, and reached pre-donation values within 3 months. The mean RLV after surgery was 37.4±4.8 %. Liver volume increased to 58.7± 7.4 % 1 week later and ultimately reached 81.5± 11.2 % at 6 months post-donation, showing that more than half of liver volume growth was achieved within 1 week after donation.

The spleen also showed marked growth within 1 week post-donation, reaching 143.1±28.8 % of pre-donation volume. Thereafter, splenic enlargement diminished gradually, ultimately ending up at 130.6±25.1 % of pre-donation volume. Lastly, mean platelet count was 85.3±21.5 % of the pre-donation value at 1 week after donation. Such a decreased platelet count persisted without a significant difference until 6 months post-donation.

We divided the ranges in splenic size and platelet count into <10, 10–30, 30–50, and ≥50 %, when compared to pre-donation values, respectively. The distributions of splenic size were 9.7 % (23/237), 25.7 % (61/237), 29.1 % (69/237), and 35.4 % (84/237) at 1 week post-donation. The patient number in the splenic size <10 and 10–30 % groups increased, and the number of splenic size ≥50 % decreased at 6 months post-donation: 17.3 % (41/237), 34.6 % (82/237), 29.5 % (70/237), and 18.6 % (44/237). Next, the platelet count distributions were 33.7 % (128/380), 48.7 % (185/380), 17.1 % (65/380), and 0.5 % (2/380), respectively, at 1 week post-donation. This distribution did not change remarkably at 6 months post-donation [33.5 % (104/315), 51.1 % (161/315), 15.9 % (50/315), and 0 % (0/315)].

Factors Influencing Liver and Spleen Recovery

The effects of clinical parameters on liver regeneration, splenic size, and platelet counts were investigated. Clinical parameters included patient age (<40 and ≥40 years), gender, the degree of steatosis (<10 and ≥10 %), and RLV (<35 and ≥35 %). Female patients showed higher peak ALT and total bilirubin levels than those of male patients ($P<0.001$). Patients

Table 1 Serial changes in parameters reflecting hepatic function and portal hemodynamic alterations across donor right hepatectomies

	Pre-donation level	Peak level	Post-donation 1 week	Post-donation 3 months	Post-donation 6 months
ALT, IU/L	26.3±24.7	249.3±180.3	96.3±60.9	25.4±12.0	22.9±14.7
Total bilirubin (mg/dL)	0.65±0.33	2.90±1.25	1.18±4.47	0.85±0.35	1.02±0.48
RLV, mL (%)	522.7±108.9		824.0±161.8	1,045.9±199.1	1,141.2±226.2
	(37.4±4.8)		(58.7±7.4)	(75.4±9.6)	(81.5±11.2)
Splenic volume (cm^3 (%))	312.1±114.1		435.8±154.4	420.2±159.2	402.1±159.6
	(100.0 %)		(143.1±28.8)	(137.4±29.7)	(130.6±25.1)
Platelet count ($\times 10^3/\mu L$ (%))	222.9±50.1		186.9±47.3	189.0±49.5	187.7±46.8
	(100.0 %)		(85.3±21.5)	(85.8±17.1)	(85.1±15.7)

ALT alanine transaminase, *AST* aspartate transaminase, *RLV* remaining liver volume

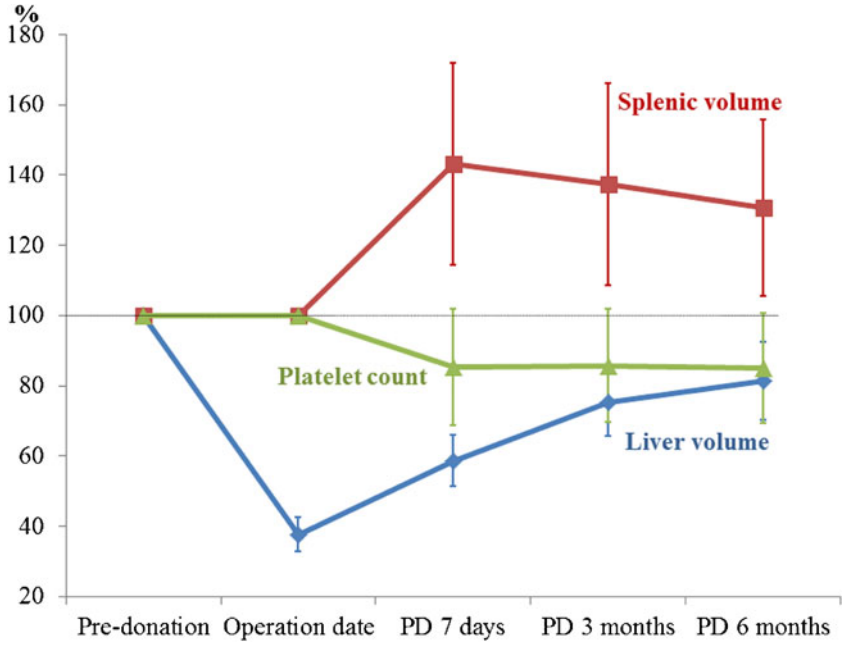

Fig. 1 Serial changes in liver volume, splenic volume, and platelet counts across donor right hepatectomies (mean±standard deviation)

with steatosis of ≥10 % exhibited a higher ALT peak than did patients with steatosis of <10 % (peak ALT; 356±253 vs. 222±145 IU/L, $P<0.001$). Additionally, patients with RLV<35 % had a significantly higher peak ALT and total bilirubin than did patients with RLV≥35 % (peak ALT and total bilirubin, 322±250 vs. 221±133 IU/L, $P<0.001$; 3.3±1.4 vs. 2.8±1.2 mg/dL, $P=0.003$).

Next, we evaluated the effects of these clinical parameters on liver regeneration, platelet count, and splenic volume (Table 2). RLV was proved to be a decisive factor for liver regeneration throughout all the post-donation periods; patients with RLV<35 % recorded more prominent regeneration than did patients with RLV≥35 % ($P<0.001$). Besides RLV, male patients showed better liver regeneration than that of female patients at 1 week post-donation (162.5±28.6 vs. 151.8±25.5 %, $P=0.001$), and patients with steatosis of ≥10 % showed more marked liver regeneration than that of patients with steatosis of <10 % at 6 months post-donation (234.8±55.0 vs. 217.7±41.3 %, $P=0.027$). In addition, patients with steatosis of <10 % showed more prominent splenic enlargement than that of patients with steatosis of ≥10 % at 1 week post-donation (455±142 vs. 430±157 %, $P=0.030$). Platelet count decreased significantly in female patients at 1 week and 3 months after donation, respectively (at 1 week, 80.4±21.8 vs. 88.0±17.2 %, $P=0.001$; at 3 months, 83.5±16.5 vs. 87.1±17.3 %, $P=0.054$).

Correlations Between Hepatic Volume, Splenic Volume, and Platelet Count

Although the correlation coefficients were not high, splenic volume was negatively correlated with platelet count at the same time point throughout all postoperative periods [$r=-0.245$, $P=0.000$ (1 week); $r=-0.300$, $P<0.000$ (3 months); $r=-0.325$, $P=0.000$ (6 months)] (Fig. 2). Similarly, RLV and splenic volume exhibited a negative, but not significant correlation, and no correlation was observed between RLV and platelet count (data not shown).

Long-Term Consequences After Donor Right Hepatectomy

Post-donation 6-month data were utilized to estimate long-term consequences. Approximately 48 % (114/237) of patients showed sustained splenic enlargement at 6 months post-donation, and 15.5 % (50/305) of patients exhibited sustained decrease in platelet count. We attempted to find a causable factor affecting such sustained consequences, which we finally could not detect (data not shown). Next, the impact of such sustained splenic enlargement and/or decrease in platelet count on donor's safety was investigated (Table 3). Patients with sustained splenic enlargement showed lower platelet count (in percent) at 1 week and 6 months post-donation than that of control patients, respectively [81.3±17.3 vs. 88.0±14.5 %, $P=0.002$ (1 week); 83.3±15.6 vs. 88.1±15.0 %, $P=0.017$ (6 months)], and patients with sustained decrease in platelet count had significantly retarded liver regeneration (in percent) at 1 week post-donation (56. 3±7.2 vs. 58.9±7.5 %, $P=0.037$) and recovered thereafter. Donor's safety was estimated in terms of liver regeneration, the levels of peak liver enzymes, and postoperative complications (Table 3). Postoperative complications were classified according to Clavien's proposal. In our series, we did not experience grade 4 or 5 complications. In overall and individual grade complications, we could not find any difference between patients with sustained splenic enlargement and/or decrease in platelet and control patients.

Table 2 Serial changes in parameters reflecting altered portal hemodynamics according to possible contributing factors after donor right hepatectomy

	Baseline data[a]	Post-donation 1 week	*P* value	Post-donation 3 months	*P* value	Post-donation 6 months	*P* value
Liver regeneration, cm^3 (%[b])							
Age (years)			0.782		0.183		0.284
<40	536±105	842±159 (158.6±26.6)		1,068±207 (203.3±38.7)		1,170±219 (219.7±41.9)	
≥40	492±113	778±157 (159.6±31.6)		996±169 (209.4±42.2)		1,062±228 (226.3±53.1)	
Gender			0.001		0.126		0.151
Male	544±108	873±148 (162.5±28.6)		1,099±192 (207.5±40.1)		1,206±221 (224.3±46.7)	
Female	484±100	730±143 (151.8±25.5)		951±175 (200.8±39.0)		1,017±180 (216.0±41.7)	
Steatosis			0.107		0.069		0.027
<10 %	512±101	802±155 (157.5±27.3)		1,016±189 (203.0±39.1)		1,102±203 (217.7±41.3)	
≥10 %	567±127	918±152 (160.4±30.0)		1,164±196 (212.6±41.0)		1,278±251 (234.8±55.0)	
RLV			<0.001		<0.001		<0.001
<35 %	452±94	815±165 (181.3±31.3)		1,064±190 (241.0±43.0)		1,171±236 (262.8±50.8)	
≥35 %	552±101	828±161 (149.2±19.8)		1,039±204 (190.6±27.4)		1,130±223 (206.0±31.2)	
Splenic size (%[c])							
Age (years)			0.375		0.402		0.681
<40	331±123	463±163 (144.2±30.0)		444±170 (136.3±31.1)		425±175 (130.1±25.6)	
≥40	271±78	376±113 (140.6±26.0)		373±113 (139.8±26.7)		352±103 (131.6±23.9)	
Gender			0.531		0.557		0.559
Male	332±123	464±163 (143.9±28.3)		445±170 (136.5±25.9)		427±176 (129.9±22.5)	
Female	273±81	380±120 (141.4±29.9)		375±117 (139.2±36.1)		353±105 (132.1±29.5)	
Steatosis			0.030		0.364		0.436
<10 %	303±112	430±157 (145.1±29.5)		413±160 (138.3±30.9)		394±162 (131.3±25.9)	
≥10 %	345±119	455±142 (134.9±24.8)		450±141 (133.9±24.9)		434±148 (128.1±21.8)	
RLV			0.947		0.217		0.929
<35 %	328±119	458±145 (142.9±25.2)		452±157 (141.1±29.0)		426±181 (130.4±23.5)	
≥35 %	305±112	426±158 (143.1±30.3)		426±181 (135.9±30.1)		392±150 (130.7±25.8)	
Platelet count, $\times 10^3/\mu L$ (%[d])							
Age (years)			0.252		0.807		0.974
<40	224±48	189±46 (86.2±22.8)		190±48 (86.0±15.5)		188±45 (85.1±13.2)	
≥40	222±51	182±50 (83.4±18.1)		187±54 (85.5±20.4)		186±51 (85.1±20.7)	
Gender			0.001		0.054		0.185
Male	219±45	191±46 (88.0±17.2)		188±45 (87.1±17.3)		187±45 (85.9±14.7)	
Female	231±55	180±49		191±57		188±51	

Table 2 (continued)

	Baseline data[a]	Post-donation 1week	*P* value	Post-donation 3months	*P* value	Post-donation 6months	*P* value
		(80.4±21.8)		(83.5±16.6)		(83.4±17.7)	
Steatosis			0.215		0.486		0.362
<10 %	222±49	184±46 (84.6±21.8)		187±48 (85.5±15.6)		186±47 (84.7±14.6)	
≥10 %	228±49	198±53 (88.1±20.3)		196±54 (87.1±22.3)		194±48 (86.7±19.3)	
RLV			0.836		0.536		0.344
<35 %	226±48	187±46 (85.2±21.5)		191±48 (86.8±21.8)		190±45 (86.5±19.1)	
≥35 %	222±50	187±48 (85.7±21.6)		189±50 (85.6±14.8)		187±48 (84.6±14.2)	

RLV remaining liver volume

[a] Baseline data means preoperative values of splenic size and platelet count and the immediate postoperative value of remaining liver volume

[b] Liver regeneration (in percent) at each period=estimated liver volume (in cubic meter) at each period/immediate postoperative value of remaining liver volume (in cubic meter)×100

[c] Splenic size (in percent) at each period=estimated splenic size (in cubic meter) at each period/preoperative splenic volume (in cubic meter)×100

[d] Platelet count (in percent) at each period=platelet count (number per microliter) at each period/preoperative platelet count (number per microliter)×100

In addition, patients with sustained splenic enlargement and/or decrease in platelet count did not show significant difference in the degree of liver regeneration and peak liver enzyme levels compared to the control patients.

Discussion

This study is one of the large-scaled studies concerning the long-term effects of donor hepatectomy in terms of physio-morphological consequences. Liver volume was driven toward the pre-donation value after a right hepatectomy, and its function stabilized gradually. Liver volume increased to >50 % of RLV until 1 week post-donation and then grew gradually to about 80 % of RLV at 6 months post-donation. Similar to the liver, the spleen reached its maximum growth within 1 week after donation. However, unlike the liver, it decreased gradually in size, arriving at a 30 % increase over the preoperative value at 6 months post-donation, and therefore, a substantial number of patients experienced sustained hypersplenism.

Although the mechanism underlying liver regeneration and compensatory splenic enlargement has been a subject of considerable controversy and debate, many researchers agree with the concept that these two organs are closely related in physio-morphological changes. Liver regenerative capacity was reported to be actively inhibited by the spleen through secretion of cytokines (i.e., transforming growth factor beta 1 and hepatocyte growth factor activator inhibitor types 1 and 2);[13] this report was supported by the observation that splenectomy enhances liver regeneration during the early regenerative phase of liver proliferation.[14] In addition, Charters et al.[15] found a similarity in the nature and growth phase between the liver and spleen in their 70 %

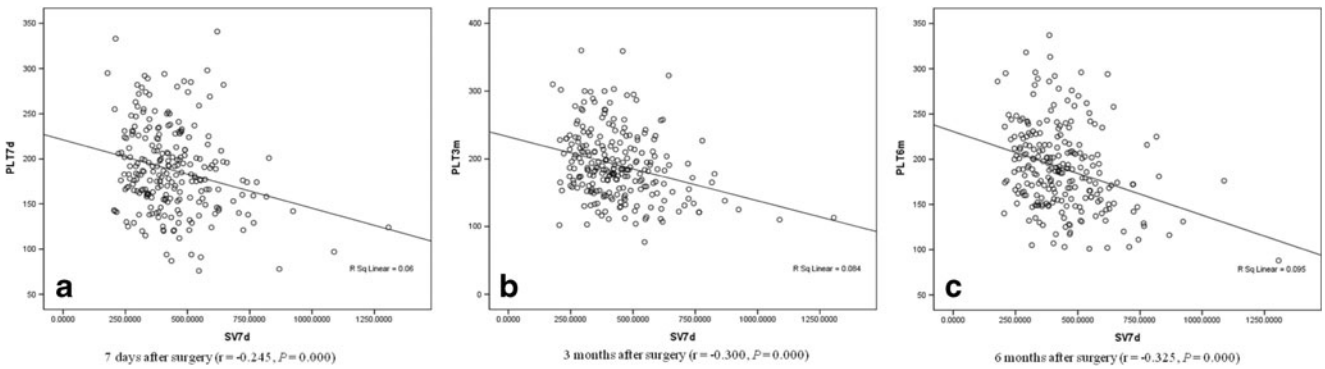

Fig. 2 Correlations between hepatic volume, splenic volume, and platelet count at the post-donation periods

Table 3 The impact of sustained splenic enlargement (≥30 %) and/or decrease in platelet count (≥30 %) at post-donation 6 months on postoperative hepatic function and complications

	Presence of sustained splenic enlargement		*P* value	Presence of sustained decrease in platelet count		*P* value
	Yes (*n*=123)	No (*n*=114)		Yes (*n*=265)	No (*n*=50)	
Final liver regeneration (%)[a]	80.3±9.1	80.7±10.4	0.767	81.2±11.5	83.0±8.3	0.354
Highest liver enzymes						
AST (IU/L)	234±143	261±219	0.242	252±191	223±101	0.283
ALT (IU/L)	253±181	271±204	0.465	263±196	241±160	0.437
Total bilirubin (mg/dL)	2.87±1.24	2.91±1.41.	0.774	2.95±1.29	2.98±1.37	0.870
Mean liver enzymes at 6 month						
AST (IU/L)	23.8±6.5	25.6±20.0	0.357	24.2±13.6	23.2±9.6	0.650
ALT (IU/L)	23.0±9.8	24.3±21.2	0.533	23.0±12.4	24.1±24.8	0.637
Total bilirubin (mg/dL)	1.15±0.59	1.06±0.47	0.173	1.13±0.52	1.00±0.37	0.107
Postoperative complications, *N* (%)						
Grade 1	10 (8.1)	16 (14.0)	0.300	36 (13.6)	2 (4.0)	0.060
Grade 2	11 (8.9)	8 (7.0)	0.639	20 (7.5)	3 (6.0)	1.000
Grade 3	7 (5.7)	11 (9.6)	0.328	23 (8.7)	4 (8.0)	1.000

ALT alanine transaminase, *AST* aspartate transaminase

[a] Final liver regeneration (in percent)=calculated liver volume (in cubic meter) at postoperative 6 months/preoperative whole liver volume (in cubic meter)×100

hepatectomized rat model and suggested that these two organs respond to common growth factors, including hepatocyte growth factor. However, most of such studies have been experimental. Even if they were clinical studies, they were based on a small or diseased population, such as patients with biliary cancer. Therefore, we think our study, which was based on sufficient number of healthy liver donors (*n*=382), could give more reliable information on the physio-morphological consequences of the liver and spleen after hepatectomy.

In our study, a close relationship between the liver and spleen was reaffirmed. RLV was negatively correlated with splenic volume, as a smaller RLV was directly related to more prominent splenic enlargement. Notably, splenic enlargement occurred 1 week after donation, whereas the liver continued growing toward its pre-donation volume, and the rate of splenic enlargement decreased. It is generally accepted that portal hemodynamic alterations at 1 week post-donation represent the maximum proliferation phase for the liver and spleen,[16,17] and portal hemodynamic alterations are stabilized thereafter. Our findings suggest that portal pressure and related secreted proteins worked as a major driving force for morphological change in the liver and spleen.

Splenic enlargement did not always induce hypersplenism as platelet count decreased. Splenic volume is just one of many factors determining platelet count. It was well-documented that a combination of factors such as portal hypertension, shortened platelet mean lifetime, decreased thrombopoietin production, and/or myelotoxic effects of alcohol or hepatitis virus contributes to thrombocytopenia.[18] A major hepatic resection itself can precipitate thrombocytopenia as a result of increased platelet consumption, possibly due to intrahepatic and splenic congestion.[7,19] Furthermore, thrombopoietin also increases immediately after hepatic resection, peaking 5 days after surgery.[19]

Mean splenic volume and platelet count at 6 months post-donation were 130.6±25.1 and 85.1±15.7 % of pre-donation values, respectively. Therefore, splenic enlargement and/or resultant hypersplenism after donor right hepatectomy should not be considered temporary episodes. We defined it as sustained splenic enlargement when splenic volume at 6 months after donation increased to ≥30 % of the pre-donation value and, as sustained, decreased in platelet count when the platelet count at 6 months post-donation decreased to 30 % or more of that of the pre-donation value. According to our definition, a substantial proportion of patients exhibited sustained splenic enlargement (48.1 %, 114/237) and/or decrease in platelet count (15.9 %, 50/315). We think that altered portal hemodynamics might have affected patients with sustained splenic enlargement and/or decreased in platelet count. We evaluated whether sustained splenic enlargement and/or decrease in platelet count could influence donor's safety in terms of the degree of liver regeneration, changes in liver enzymes, and postoperative complications, and found that it did not endanger donor's safety.

We acknowledge that the present study had several limitations. Due to the limitations of retrospective data, some patients lacked data from certain period(s), which could have hampered a balanced comparison. In addition, differences in the measurement methods of the liver and splenic volume can lead to some bias; the former utilized a summation-of-volumes technique using a workstation, and the latter exploited topographical measurements. Lastly, we later realized that 6 months was too short to evaluate long-term consequences. Our results should thus be supported by studies that include longer recovery periods.

In conclusion, the liver showed consistent growth toward pre-donation volume after donor hepatectomy. However, the spleen showed rapid growth within 1 week after surgery but then decreased gradually in size, arriving at a 30 % increase over the pre-donation value at 6 months post-donation. A substantial portion of patients exhibited sustained splenic enlargement and/or decreased in platelet count at 6 months after donation. However, such a change did not endanger donor's safety. More prolonged and extensive study is needed to investigate the duration and long-term consequences of such effects and the association with altered portal hemodynamics.

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