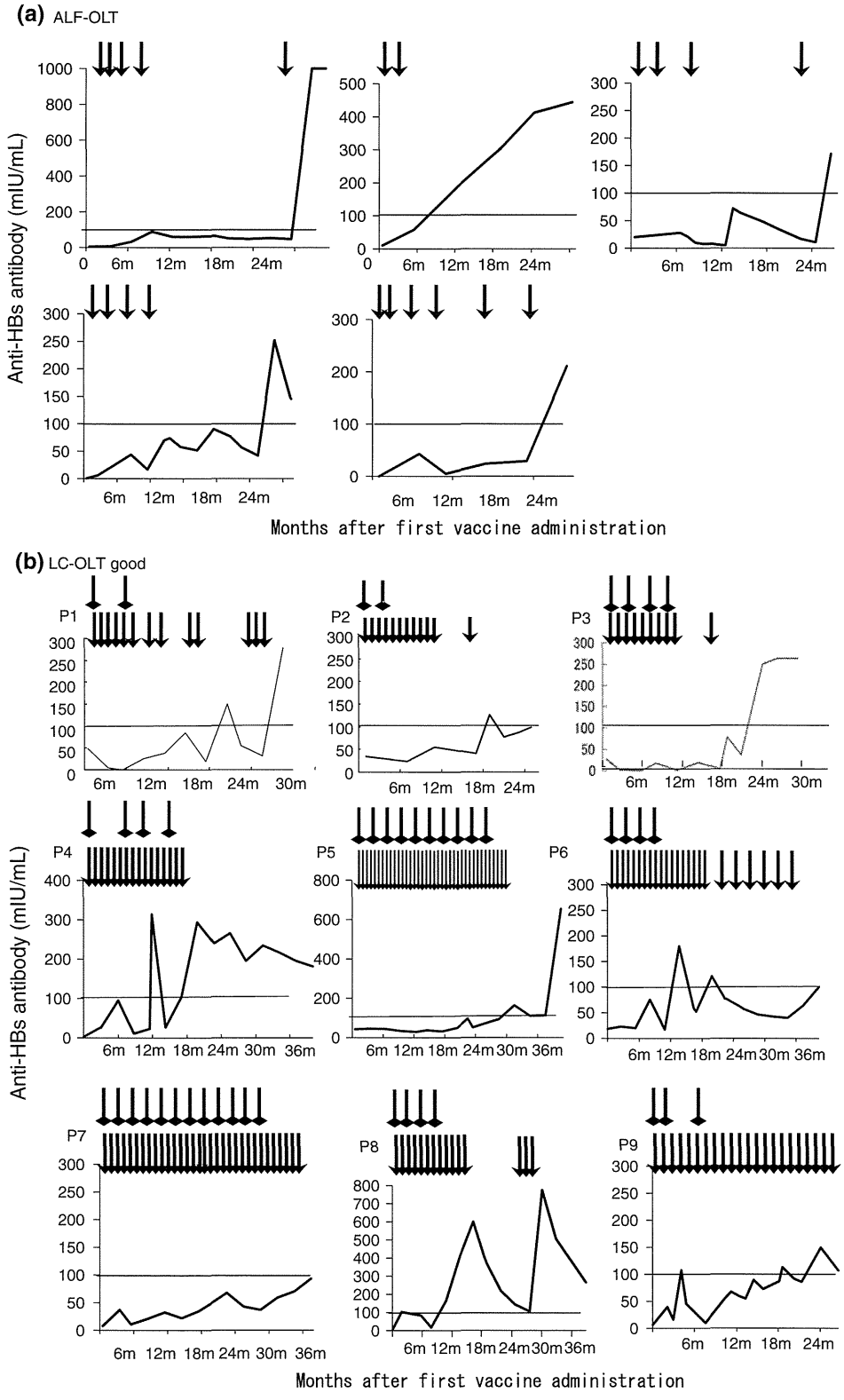

Fig. 1 Individual patients' timecourse of anti-HBs antibody titer after vaccine administration. The timecourse of the anti-HBs antibody titer after the first vaccine administration is shown. The *arrowhead* indicates a vaccine administration point, and the *square head* indicates an HBIg administration point. **a** Patients who received orthotopic liver transplantation (OLT) due to hepatitis B-related acute liver failure (ALF-OLT). All patients had a good response to vaccination. **b** Patients who received OLT due to liver cirrhosis with a good response to vaccination (LC-OLT good). **c** LC-OLT patients with a poor response to vaccination (LC-OLT poor)

Although monotherapy with HBIg or LAM resulted in a high rate of recurrence, a combination of these agents has been administered with reasonable success. In 1998, Markowitz et al. [20] reported no recurrences after 1 year of combination therapy. Since HBIg is very expensive, several reports have described modified combination

Fig. 1 continued

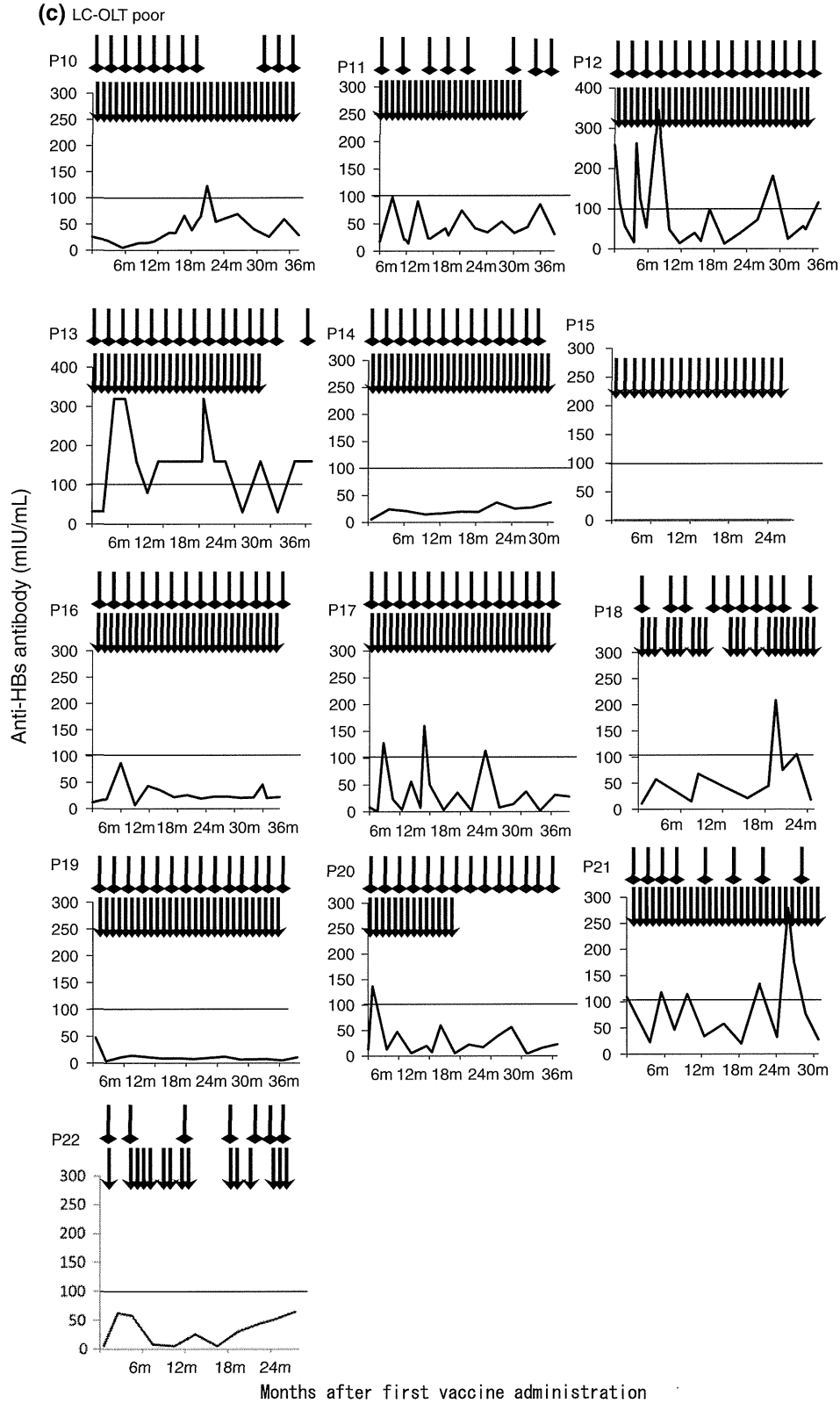

Table 4 LC patient characteristics

Characteristics of recipients													Characteristics of donors						
Patient's number	Response to vaccine	Age (year) at OLT	Sex	HBsAg (mIU/mL) at OLT	HBsAb at OLT	HBeAg/HBeAb at OLT	HBV DNA (logcopies/mL) at OLT	MELD at OLT	HCC at OLT	Time of vaccination (months post-OLT)	HBsAb (mIU/mL) at vaccine	NA at vaccine	Age at OLT	Sex	Blood relation	ABO compatibility	HBcAb	HBsAb	HBsAb (mIU/mL)
1	Good	56	M	100	–	–/+	<3.7	17	+	51	49	LAM	52	F	–	Compatible	–	–	<0.1
2	Good	48	M	>2000	–	+/+	3.5	20	+	24	23	LAM	46	F	–	Compatible	+	+	134
3	Good	44	M	100	–	+/–	<3.7	12	–	55	1	LAM	48	F	+	Identical	+	+	189
4	Good	50	M	>2000	–	+/–	3.4	9	+	42	25	LAM + ADV	48	F	–	Compatible	+	+	627
5	Good	54	M	>2000	–	–/+	3.8	15	–	40	43	LAM + ADV	48	F	–	Compatible	–	–	<0.1
6	Good	57	M	>2000	–	–/+	2.7	15	+	45	18	LAM	53	F	–	Identical	–	–	<0.1
7	Good	48	M	642	–	+/–	4.8	17	–	29	7	LAM	44	F	–	Compatible	+	+	179
8	Good	47	F	>2000	–	+/–	4.5	12	–	19	6	LAM	50	M	–	Compatible	+	+	1000
9	Good	55	M	>2000	–	+/–	6.1	21	+	49	6	LAM + ADV	48	M	+	Identical	+	+	133
10	Poor	52	M	>2000	–	+/–	5.3	8	+	25	4	LAM	21	M	+	Compatible	+	+	1000
11	Poor	62	M	>2000	–	–/+	<2.6	8	+	13	17	LAM + ADV	36	M	+	Identical	–	–	<0.1
12	Poor	39	M	>2000	–	+/–	<2.6	7	–	30	169	LAM	35	F	+	Identical	–	–	<0.1
13	Poor	49	M	100	–	–/+	4.0	21	+	107	32	LAM	22	F	+	Identical	–	–	<0.1
14	Poor	26	M	100	–	+/–	5.5	20	+	75	30	LAM	53	M	+	Identical	+	+	397
15	Poor	54	F	100	–	+/–	4.6	22	+	55	1	LAM	28	M	+	Identical	–	–	<0.1
16	Poor	50	M	160	–	–/+	2.7	18	+	38	6	LAM	25	M	+	Compatible	+	–	<0.1
17	Poor	44	M	>2000	–	–/+	<2.6	15	–	32	14	LAM	47	F	+	Compatible	–	–	<0.1
18	Poor	55	F	>2000	–	+/–	2.8	10	+	19	10	LAM + ADV	51	F	+	Identical	+	+	44
19	Poor	54	M	>2000	–	–/–	<2.6	8	+	18	47	ETV	49	F	–	Compatible	+	+	1000
20	Poor	63	M	1740	–	–/+	<2.6	12	–	17	42	LAM + ADV	36	M	+	Identical	–	–	0.2
21	Poor	58	M	35	–	–/+	<2.6	16	–	16	19	ETV	33	F	+	Identical	–	–	0.3
22	Poor	61	M	>2000	–	–/+	2.9	15	+	68	5	LAM	26	M	+	Identical	–	–	<0.1

NA nucleos(t)ide analogue, *LAM* lamivudine, *ADV* adefovir dipivoxyl, *ETV* entecavir, *HBcAb* anti-HBc antibody, *HBsAb* anti-HBs antibody

Table 5 Patient characteristics according to vaccine responsiveness in LC (univariate analysis)

N	Good responders 9	Poor responders 13	*p* value
Recipient related factors			
Age at OLT	50 (47–55)	54 (46–59)	0.546
Sex (male)	8 (88 %)	11 (84 %)	0.774
Time of vaccination (months after OLT)	42 (26–50)	30 (17–61)	0.442
HBsAg at OLT (≥1500 IU/l)	6 (66 %)	8 (61 %)	0.805
HBeAg positive at OLT	6 (66 %)	5 (38 %)	0.190
HBV DNA at OLT (≥3.7 logcopies/mL)	4 (44 %)	4 (30 %)	0.513
MELD at OLT	15 [12–18]	15 [8–19]	0.480
Child-Pugh score at OLT	10 [8–10]	9 [6–11]	0.845
HCC at OLT (+)	6 (66 %)	9 (69 %)	0.899
Anti-HBs antibody titer at the start of vaccination	18.6 (6.4–34.6)	17.4 (5.9–37.1)	0.920
Nucleos(t)ide analogue (LAM/LAM + ADV/ETV)	6/3/0	8/3/2	0.312
Tacrolimus/cyclosporinA	6/3	11/1#	0.148
Tacrolimus level (ng/mL)	4.7 (3.0–5.6)	3.8 (2.9–5.8)	0.744
Donor-related factors			
Age at OLT	48 (47–51)	33 (25–48)	0.019*
Sex (M)	2 (22 %)	7 (53 %)	0.138
ABO (identical)	3 (33 %)	9 (69 %)	0.093
Blood relation (no)	7 (77 %)	1 (7 %)	<0.001*
Anti-HBs antibody titer (>100)	6 (66 %)	3 (23 %)	0.038*
Anti-HBc antibody (+)	6 (66 %)	5 (38 %)	0.190
Anti-HBc(+)/anti-HBs(+)	6 (66 %)	4 (30 %)	0.093
Anti-HBc(+)/anti-HBs(−)	0 (0 %)	1 (7 %)	0.297
Anti-HBc(−)/anti-HBs(+)	0 (0 %)	0 (0 %)	–

MELD Model for End-stage Liver Disease, *HCC* hepatocellular carcinoma, *LAM* lamivudine, *ADV* adefovir dipivoxyl, *ETV* entecavir

One patient received no calcineurin inhibitor

Table 6 Multiple logistic analysis of factors associated with good responses to HBV vaccine in LC

N	Odds ratio	95 % CI	*p* value
Age at OLT (>47)	5.4	0.300–214.000	0.244
Blood relation (no)	29.4	2.551–984.110	0.005*
Anti-HBs antibody titer (>100)	5.0	0.343–149.947	0.233

Note: Variables significant at $p < 0.05$

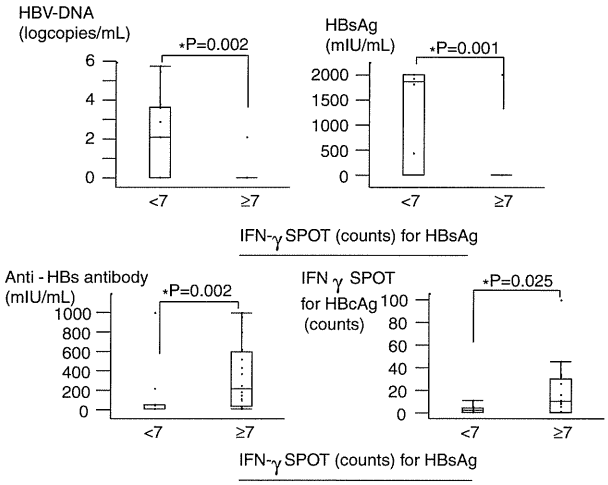

Fig. 2 The clinical characteristics of the non-OLT patients with strong HBsAg-specific T cell interferon-γ response. The clinical characteristics of the non-OLT patients showing strong HBsAg-specific T cell immune responses by enzyme-linked immunospot (ELISPOT) assay are shown. Those patients with stronger HBsAg-specific CD4 T cell IFN-γ response (equal or more than the median; 7 spots) showed lower HBV DNA, lower HBsAg, higher anti-HBs antibody titer, and higher HBcAg-specific immune responses

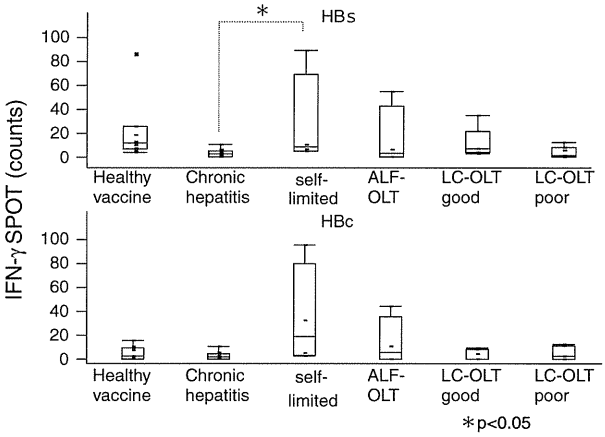

Fig. 3 Cellular immune responses against HBsAg including OLT patients. The number of spots due to interferon-γ response in the ELISPOT assay for HBsAg (*upper figure*) and HBcAg (*lower figure*) is shown. *1* Healthy vaccine: healthy controls who were positive for anti-HBs antibodies with HBV vaccine ($n = 11$). *2* Chronic hepatitis: chronic hepatitis B patients ($n = 10$). *3* Self-limited: self-limited acute hepatitis B patients who showed serum anti-HBs antibody-positive/HBcAb-positive with no HBsAg or HBV-DNA ($n = 5$). *4* ALF-OLT: post-OLT acute liver failure patients ($n = 4$). *5* LC-OLT good: post-OLT liver cirrhosis patients who showed good response to vaccine ($n = 8$). *6* LC-OLT poor: post-OLT liver cirrhosis patients who showed poor response to vaccine ($n = 7$). Values are plotted as median (range)

therapies. We previously have shown that long-term LAM with short-term, high-dose HBIg followed by low-dose HBIg (sufficient to maintain an anti-HBs antibody titer of >10 mIU/mL) is cost-effective and powerful enough to control HBV recurrence after LDLT [13]. With this cost-saving method, no clinical evidence of HBV recurrence has been seen.

In 2000, Sanchez-Fueyo et al. [21] reported an 82 % response to HBV vaccination after OLT. These researchers

used three cycles of double-dose recombinant HBsAg vaccine for immunization over 6 months, with a target antibody titer of >10 mIU/mL. The cohort included six acute infected patients and 11 chronic carriers. However, recent reports show that chronic HBV carrier recipients did not respond well, with response rates ranging from 7.7 to 12.5 % [22, 23]. Acute HBV-infected patients who underwent OLT were often positive for the anti-HBs antibody even before OLT, with strong immune responses. Such patients might be expected to respond well to vaccination, since these individuals (unlike chronic carriers) have not developed a tolerance to HBV. In our patients, five acute infected patients showed good responses to vaccination, responding after a median of only four vaccinations. These results indicate that while acute HBV-infected patients are good candidates for HBV vaccination post-OLT; chronic HBV carriers are poorer candidates for this protocol. However, as some HBV carriers did respond to vaccination; further studies should be performed to clarify the differences between the good and poor responders.

Several reports have identified the differences between good responders and poor responders in non-HBV-infected patients who received HBcAb-positive donor livers. Lacking previous HBV exposure, these recipients should not have developed tolerance to the virus and so should have been good responders. Of these, good responses were seen in pediatric cases where the recipients had higher anti-HBs antibody titers at the time of OLT and lower tacrolimus levels at the time of vaccination [24]. The present study revealed that repeated vaccine administration resulted in successful immunization in 40 % of the LC-OLT recipients. For these recipients, the strength of the response did not correlate with recipient characteristics, not even with age, one of the most important factors for successful immunization [25]. In contrast, the characteristics of the donor were important. The good responders' donors were relatively high in age, non-blood-related and had high anti-HBs antibody titers before donation. Note that, in our trial, the term "non-blood-related donor" indicates the spouse of the recipient, since deceased donor liver transplantation is not widely accepted in Japan [26]. The donors with high-titer anti-HBs antibody probably were infected with HBV by the recipients after their marriage, resulting in the anti-HBs antibody boost. These donors' immune systems should not have developed tolerance to the virus. This elevated immunity might be the reason why our patients had relatively better outcomes following vaccination than those of previous reports [27]. Adoptive immune transfer of HBV-specific immune response could be possible [28]. For successful transfer of immune memory to the recipients, the anti-HBs antibody titer of the donors should be high, and vaccine-induced anti-HBs antibody might be less effective than antibodies produced in a previous self-limited infection. Luo et al. [29] have shown that a particularly high anti-HBs antibody titer (>1000 IU/L) in the donor is essential for adoptive immune transfer. The results of the present study suggest that HBV vaccination of non-blood-related living donor candidates having a lower anti-HBs antibody titer (<100 mIU/mL) might facilitate improved vaccine response post-OLT in LC recipients.

The present study of HBV vaccine efficacy in ALF-OLT and LC-OLT patients revealed that the vaccine response depended on the immune tolerance to the virus in both recipients and donors. The liver is the biggest immune organ in the abdomen and so can play a critical role in immune responses. Multiple populations of non-hematopoietic liver cells, including sinusoidal endothelial cells, stellate cells located in the subendothelial space, and liver parenchymal cells, take on the roles of antigen-presenting cells [30]. The viral-specific immune competence of the grafted liver might overcome the general immunotolerance to the virus in chronic HBV carriers.

In conclusion, patients who received OLT due to acute infection of HBV were good candidates for HBV vaccination. The chronic HBV carrier recipients who received livers from donors who were non-blood-related (i.e, the recipient's spouse) and who harbored high anti-HBs antibody titers were the best candidates for HBV vaccine administration. Vaccine-induced, HBV-specific immune responses were strong enough to induce not only humoral but also cellular responses in vitro.

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Conflict of interest The authors declare that they have no conflict of interest.

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HOW I DO IT

New Surgical Approach to Large Splenorenal Shunt in Living Donor Liver Transplantation: Diversion of SMV and SPV Blood Flow

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Abstract
Introduction The management of a large splenorenal shunt is important because it affects recipient outcome, particularly in living donor liver transplantation.
Methods To manage large splenorenal shunts in living donor liver transplantation, we diverted superior mesenteric vein and splenic portal vein blood flow by ligation at the root of the splenic portal vein.
Result This procedure was applied for five patients in whom superior mesenteric vein blood flow had been completely stolen by a splenorenal shunt preoperatively. Postoperative course was excellent in all cases.
Conclusion This technique completely prevents morbidity related to large splenorenal shunts after living donor liver transplantation.

Keywords Living donor liver transplantation · Splenorenal shunt · Shunt diversion

Introduction

A large splenorenal (SR) shunt can induce the steal phenomenon, diminishing graft portal venous flow (PVF) immediately after liver transplantation or in certain posttransplant conditions such as acute rejection or severe ischemic damage, causing increased intrahepatic vascular resistance.[1–3] Portal hypertension may persist more strongly and continuously in adult living donor liver transplantation (LDLT) than in deceased donor liver transplantation (DDLT). In addition, adequate graft PVF is essential for the rapid regeneration of small partial grafts after adult LDLT to meet the metabolic demands of the recipient.[4,5]

Several approaches have been applied to treat large SR shunt in DDLT and LDLT. Direct division of the SR shunt with splenectomy has been used, but splenectomy in DDLT and LDLT may be technically difficult and even more dangerous than normal due to the increased incidence of portal vein complications.[6,7] In contrast, ligation of the left renal vein (LRV) is a simple and safe procedure for patients with a large SR shunt. However, this procedure has a potential risk in terms of detrimental effects on renal function.[1,8,9]

We describe the management of a large SR shunt by diversion of superior mesenteric vein (SMV) and splenic portal vein (SPV) blood flow by ligation at the SPV root. We have applied this procedure in adult LDLT patients in whom SMV blood flow had been completely stolen by a SR shunt preoperatively, resulting in an excellent postoperative course.

Methods

SR shunts are evaluated by three-dimensional computed tomography (3D-CT) and Doppler ultrasonography (US)

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before LDLT. We assess the patency and flow direction of the main portal vein (PV) and SPV and detect the size and PVF of the SR shunts. A large SR shunt is defined as a shunt with diameter of >10 mm and PVF of >400 ml/min.

The recipient operation is performed in piggyback fashion. After complete graft revascularization, we manage a large SR shunt according to preoperative portal venous hemodynamics and intraoperative PVF of the graft. In patients showing partial steal of SMV blood flow by the SR shunt preoperatively and in whom PVF of the graft is measured as <1,000 ml/min, we dissect the shunt at the site of inflow to the LRV, with or without splenectomy. In patients showing complete steal of SMV blood flow by the SR shunt preoperatively, we divert SMV and SPV blood flow by ligation at the SPV root for prophylactic management of the large SR shunt as follows. The main PV is dissected towards the upper edge of the SPV root (Fig. 1a). After tunneling of the SMV, tape is introduced above the main PV and SMV (Fig. 1b). When the lower edge of the SPV root can be exposed safely by pulling the tape caudally, the SPV root is encircled and tied from the upper side using nonabsorbable sutures (Fig. 1c). In patients for whom the above-mentioned approach to the SPV root cannot be carried out safely, ligation is performed as follows. After the dorsal side of the SPV root is dissected from the retroperitoneal tissue, a nonabsorbable suture is introduced behind the SPV root (Fig. 2a). After tunneling of the SMV, another suture is introduced above the main PV and SMV (Fig. 2b). After both sutures are tied at the lower side, the suture above the main PV and SMV is pulled up over the pancreas (Fig. 2c). Using this method, the SPV root can be safely encircled and tied by the suture (Fig. 2d). The SR shunt is not dissected, and blood from the spleen can flow into the LRV via the SR shunt. In this method, the liver graft is supplied with PVF consisting of SMV blood flow alone. Graft PVF is measured by Doppler US before and after the diversion of SMV and SPV blood flows.

Statistical Analysis

Values are expressed as the mean ± standard error of the mean. Statistical analysis was performed using Student's *t* test and the Mann–Whitney test. The level of significance was defined as $p<0.05$.

Results

Between August 1996 and December 2011, a total of 280 LDLTs were performed at Okayama University Hospital. Based on preoperative evaluations using 3D-CT and Doppler US, we identified 25 patients with a spontaneous large SR shunt. In ten of these 25 patients, preoperative direction of blood flow in the SPV was hepatopetal, and SMV blood flow was not stolen by the SR shunt. In the remaining 15 patients, the direction of preoperative blood flow in the SPV was hepatofugal. Of these 15 patients, SMV blood flow showed partial steal by the SR shunt in eight patients and complete steal by the shunt in the other seven patients. The above-mentioned surgical techniques were applied in five of these seven patients.

Two of these seven patients, who were treated before the introduction of diversion of SMV and SPV blood flow at our institution, developed postoperative steal of the graft PVF by a large SR shunt. In one of these patients in whom the SR shunt was not occluded during the transplant procedure in the early stage of our LDLT program, graft PVF was completely stolen by the preserved SR shunt on postoperative day (POD) 9 due to steroid-resistant acute rejection. Although we dissected the SR shunt at the site of inflow to the LRV on POD 9 while commencing treatment for rejection, liver graft function deteriorated rapidly, and the patient died on POD 39. In the other patient, who underwent ligation of the SR shunt at the site of inflow to the LRV during the transplant procedure, graft PVF was completely stolen by the residual SR shunt on POD 2 due to severe ischemic graft injury. We diverted SMV and SPV blood flow by ligation at the SPV root on POD 2, leading to the recovery of liver graft function.

The remaining five of the seven patients with preoperative complete steal of SMV blood flow by the SR shunt underwent diversion of SMV and SPV blood flow during the transplant procedure. Mean graft weight was 641±47 g (range, 482–767 g), and mean graft-to-recipient body weight ratio was 0.84±0.06 % (range, 0.70–1.05 %). Mean blood loss was 2,495±908 ml (range, 800–5,100 ml), and mean operative time was 543±28 min (range, 490–599 min). The mean PVF of grafts in these five patients before SR shunt management was low (582±67 ml/min), but it increased significantly to 1,361±124 ml/min after diversion of SMV and SPV blood flow.

In 11 patients, the SR shunt was dissected at the site of inflow to the LRV. Among these 11 patients, graft PVF was stolen by the residual SR shunt in two patients, and portal vein thrombosis derived from the SR shunt developed in another two patients. In contrast, in the five patients who underwent diversion of SMV and SPV blood flow, there was no posttransplant morbidity related to the SR shunt and no portal vein complications. No mortality was encountered, and the mean length of postoperative hospital stay was 50±3.8 days (range, 41–60 days).

Discussion

The optimal management for a spontaneous large SR shunt remains controversial in liver transplantation. In adult

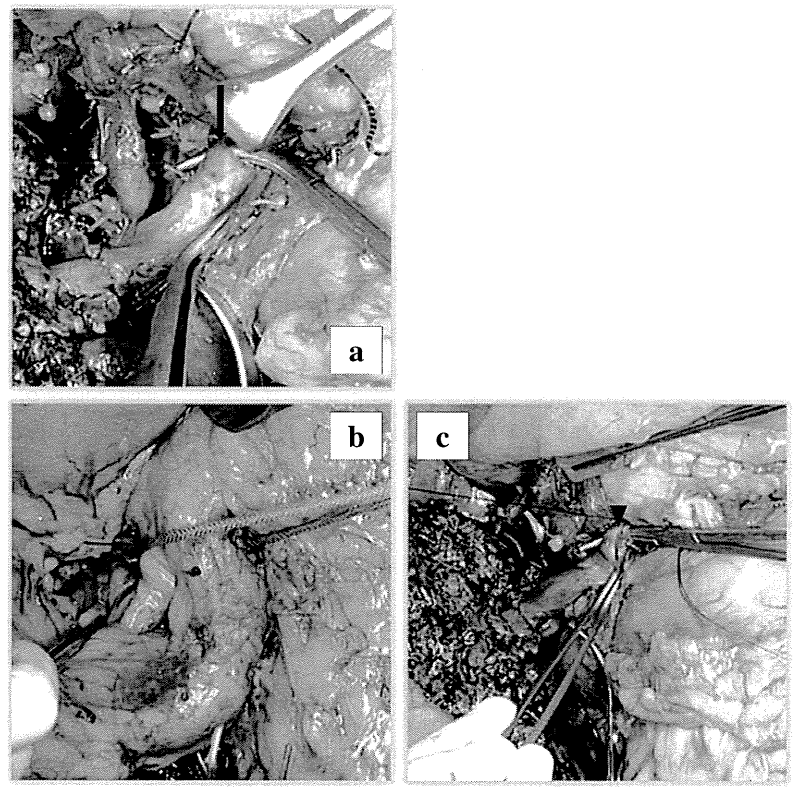

Figure 1 **a** The main PV is dissected towards the upper edge of the SPV root. In this case, the left coronary vein (*arrow*) is transected. **b** Tunneling of the SMV is performed, and the tape is introduced above the main PV and SMV. **c** The SPV root (*arrowhead*) is encircled from the upper side and is tied using a nonabsorbable suture.

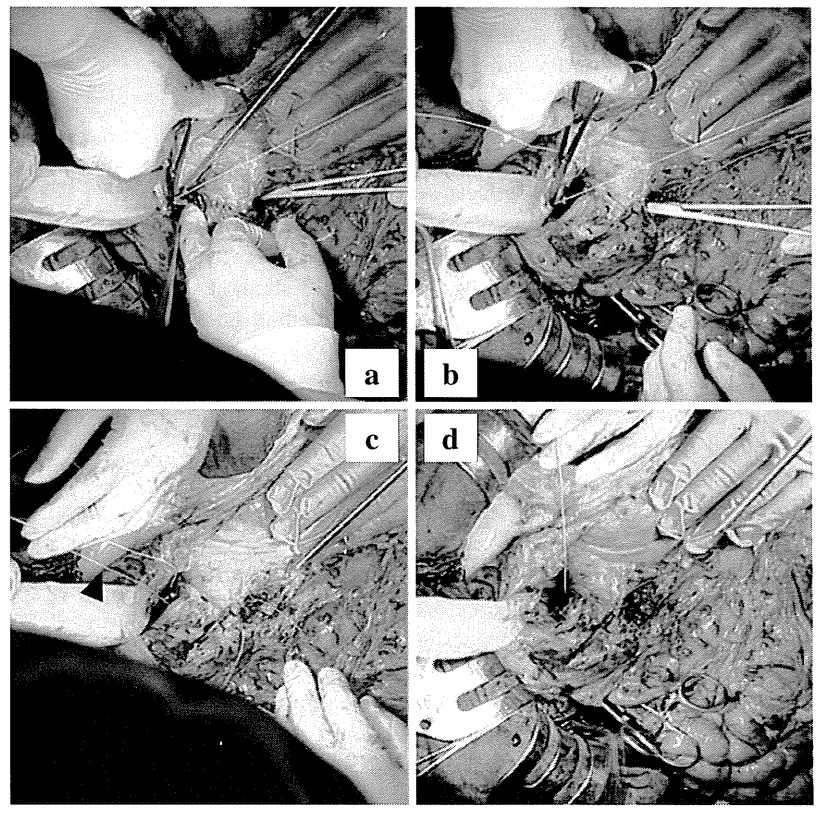

Figure 2 **a** After the dorsal side of the SPV root is dissected from the retroperitoneal tissue, a nonabsorbable suture is introduced behind the SPV root. **b** After tunneling of the SMV, the other suture is introduced above the main PV and SMV. **c** After both sutures are tied at the lower side, the suture above the main PV and SMV (*arrowhead*) is pulled up over the pancreas. **d** The SPV root can be safely and promptly encircled and tied by the suture.

LDLT, as sufficient restoration of the liver vascular bed cannot be achieved in the early postoperative period; posttransplant portal hypertension caused by acute rejection or severe ischemic damage is more severe than in DDLT. The steal of graft PVF by the preserved large SR shunt might thus be more likely in adult LDLT than in DDLT. Based on these issues, several authors have reported that prophylactic management of large SR shunts is necessary to achieve good patient and graft survival, particularly in association with adult LDLT.[1,2,8]

We have introduced a method of diverting SMV and SPV blood flow for the prophylactic management of a large SR shunt in LDLT. Indications for this method were decided according to the preoperative assessment of portal venous hemodynamics, including direction of blood flow in the main PV and the degree of steal of SMV blood flow by the SR shunt. We have applied this method for five patients in whom SMV blood flow had been completely stolen by the SR shunt preoperatively, resulting in excellent postoperative course without morbidity related to the shunt or portal vein complications.

Large SR shunts that have resulted in complete steal of SMV blood flow via the SPV before liver transplantation can often cause the steal of graft PVF immediately after liver transplantation or in various posttransplant conditions causing increased intrahepatic vascular resistance, such as acute rejection or severe ischemic damage.[1–3,8,9] In addition, such SR shunts provoke phlebosclerosis and narrowing of the main PV, intensifying the steal of graft PVF and requiring replacement of the main PV using an interposed vein graft. Several approaches to large SR shunts have thus been applied in liver transplantation.

Ligation of the LRV is a simple, safe procedure, but has a potential risk of detrimental effects on renal function.[1,8,9] Direct division of the SR shunt with splenectomy is technically difficult and is associated with an increased incidence of portal vein complications.[6,7] Ligation of the SR shunt at the site of inflow to the LRV is an effective method but carries the risk of postoperative steal of graft PVF by the development of other residual SR shunts, leading to graft dysfunction.[1,8] On the other hand, the diversion of SMV and SPV blood flow by ligation at the SPV root is a reliable method to ensure prevention of steal from the graft PVF by the SR shunt and to decrease the incidence of portal vein complications.

This method of diverting SMV and SPV blood flows poses issues in terms of the complexity of procedures and the risk of bleeding. However, in our experience, ligation of the SPV root can be performed safely and without bleeding, since collateral vessels around the head of the pancreas are rare because of the large SR shunt. Furthermore, when the SPV root cannot be safely approached from the upper side, we perform the ligation using the procedures described in Fig. 2.

Adequate PVF is essential for postoperative regeneration of the liver after partial liver transplantation.[4,5] Conversely, excessive PVF causes tissue injury in the liver graft and inhibits postoperative liver regeneration. Several groups have thus tried to maintain graft PVF and/or portal venous pressure at an optimal level by selecting occlusion or preservation of the existing portosystemic shunt.[4,10,11] In the present study, diversion of SMV and SPV blood flows by ligation at the SPV root increased graft PVF to optimal levels, as suggested in previous reports.[4,10] Although intraoperative assessment of portal venous pressure was not undertaken in our study, SMV blood flow alone, without SPV blood flow, might be adequate to achieve postoperative liver regeneration of partial liver grafts.

Conclusion

We have applied a diversion method of SMV and SPV blood flow by ligation at the SPV root for prophylactic management of large SR shunts, which had stolen SMV blood flow completely before LDLT. This new surgical approach to large SR shunts can be performed safely and completely prevents morbidity related to such shunts after LDLT.

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Laparoscopy-Assisted Hybrid Left-Side Donor Hepatectomy

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Abstract
Background Laparoscopic liver resection developed for live liver donors has the advantage of reducing the physical and mental stress in donors. However, its safety and efficacy still remain to be established. We aimed to evaluate the feasibility, safety and efficacy of laparoscopy-assisted hybrid donor hepatectomy (LADH) to obtain left side grafts.
Patients and methods A total of 31 consecutive live liver donors of left side liver grafts underwent LADH, including left lateral segmentectomy ($n = 17$) and left liver resection with or without the caudate lobe ($n = 14$) (LADH group). We compared the clinical data between the LADH group and the group of donors in whom traditional open donor hepatectomy was performed to procure the liver graft (open donor hepatectomy [ODH] group, $n = 79$).
Results Laparoscopy-assisted hybrid donor hepatectomy was feasible in all patients, and there was no mortality over a follow-up period of 13.9 ± 9.8 months. The operative time to procure a left-lobe graft was significantly longer in the LADH group (510 ± 90 min) than in the ODH group ($P < 0.001$). A large right lobe on CT (RPv distance) was identified as a significant risk factor for prolonged operative time ($P = 0.007$). Evaluation using the SF36-v2 questionnaire revealed faster recovery of the physical component summary score and bodily pain score in the LADH group than in the ODH group.
Conclusions Laparoscopy-assisted hybrid donor hepatectomy for procuring left side grafts was safe and effective up to the left liver with the caudate lobe. Left-lobe LADH in donors with a large right lobe should be carefully planned in view of the potential surgical difficulty.

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Introduction

In spite of the growing number of liver transplantations from brain-dead donors around the world, donor shortage still remains a significant problem. As a result, living donor liver transplantation (LDLT) is still necessary in Japan as well as other Asian and Western countries. Needless to say, the most important issue in LDLT is donor safety, and several reported donor deaths emphasize the great importance of this factor, and even minor morbidities should be minimized with the surgery conducted by an experienced surgeon [1, 2]. Donor surgery in live donors substantially affects quality of life, with the patients often developing wound infection, pain, and deformity [3–5]. A recent report of donor morbidities in Japan showed that the incidence of donor surgery-related morbidities was 8.4 % in total, and the leading morbidity was bile leak (2.6 %), followed by wound infection (1.2 %) [5].

Laparoscopy-assisted hybrid hepatectomy or laparoscopic liver resection has been developed for live liver graft donors, as well as for the treatment of benign or malignant tumors [3–6]. Several studies have shown its advantage over traditional open surgery in reducing the physical and emotional stress experienced by patients [7–13]. However, its safety and efficacy remain to be established.

Among the surgeries on live donors to procure liver grafts, that for obtaining a "left lobe including the caudate" graft is technically the most difficult, and very limited studies have reported the use of laparoscopic procedures to harvest left liver plus caudate lobe grafts [9]. Left liver plus

caudate lobe grafts have been used to obtain the maximum graft volume from the left side of the donor liver in adult-to-adult LDLT [14, 15]. It is important to adopt this principle, regardless of whether a laparoscopy-assisted procedure or traditional open surgery is employed.

We have experience in performing more than 140 live donor hepatectomies, as previously reported [16]. We also have sufficient experience in performing laparoscopy-assisted hepatectomy for the treatment of liver tumors. Based on this considerable experience, we began to perform laparoscopy-assisted hybrid donor hepatectomy, initially to obtain left lateral section grafts, and then, with accumulating experience, first, left liver without the caudate grafts, and finally left liver plus caudate lobe grafts.

The aim of the present study was to evaluate the safety and efficacy of laparoscopy-assisted hybrid donor hepatectomy (LADH) to procure left-side grafts, including left lateral section, left liver without the caudate, and left liver plus caudate lobe grafts.

Patients and methods

The study protocol was approved by the Human Ethics Review Committee of Osaka University Graduate School of Medicine (No. 750). A signed consent was obtained from each donor prior to operation. The study protocol was registered in the UMIN clinical trial registry (ID: UMIN000003886).

Study design

The study was a non-randomized prospective cohort study. The primary endpoint was mortality and morbidity of laparoscopy-assisted hybrid donor hepatectomy, and the secondary endpoint was the postoperative quality of life (QOL) of the living donors as evaluated in terms of analgesic requirement and the SF36v2 questionnaire for postoperative QOL.

Donor evaluation

Donor evaluation was based on the criteria approved by the ethics review committee of Osaka University. All living liver donors were adults between 20 and 65 years of age. Donor candidates with systemic diseases such as hypertension, diabetes mellitus, or psychiatric disease, and those receiving medications for any systemic disease were strictly excluded. Preoperative evaluation consisted of a complete history and physical examination, and laboratory tests (complete blood count, blood chemistry, coagulation profile, hepatitis B or C virus markers, and serological profiles for other infectious diseases). Donors also underwent chest and abdominal radiography, four-phase multidetector computed tomography (MD-CT) and drip-infusion cholangiography computed tomography (DIC-CT) with three-dimensional reconstruction. Liver volumetric analysis was conducted routinely with the Virtual Place software ver. 2.0 (AZE, Tokyo, Japan) and/or the Synapse Vincent 3D image analysis system (Fujifilm Corporation, Tokyo, Japan).

Graft selection

The criteria for donor selection have been described previously [16]. Briefly, the graft type was determined by the results of the volumetric study with MD-CT. The requirements for living donation were (1) an estimated volume of the remnant liver of more than 35 % of the whole liver volume of the donor, and (2) an estimated donor graft liver volume of more than 40 % of the recipient's standard liver volume (SLV).

Donor surgery

Open donor surgery

The methods employed for donor hepatectomies have been described previously [16]. All donors received a midline incision with bilateral subcostal incisions (Mercedes incision). Big incisions were an essential part of open donor surgery to secure the best possible field and assure donor safety during the operation. The bilateral costal incision was shorter in left lateral sectionectomy than in left lobectomy. Standard total length of incision was 25 cm in left lateral sectionectomy and 40 cm in left lobectomy. Surgery has been performed under general anesthesia without epidural anesthesia since July 2009. Basic techniques for donor hepatectomy were based on the strategy of no metal clips, no inflow occlusion, and minimal dissection of the liver hilum, as described previously [16].

Laparoscopy-assisted hybrid donor surgery (LADH)

A midline incision about 7 cm long was first made, and later extended an additional 1 cm or more, as needed. The round ligament and falciform ligament were divided. Liver wedge biopsy was obtained from segment 3 of the liver and sent for histopathological evaluation. A Gelport was placed and a 12 mm trocar was inserted through the Gelport, followed by establishment of pneumoperitoneum at 10 cm H_2O. A flexible 10 mm scope was used for the laparoscopic procedure. A 12 mm trocar was inserted at the umbilicus, and then the scope was reinserted from this second trocar, after which 5 mm trocars were placed as shown in Fig. 1, two for left lateral sectionectomy or three for left lobectomy. The left triangular ligament was

dissected up to the left hepatic vein under either full laparoscopic guidance or as a hand-assisted maneuver. For obtaining a left with caudate lobe graft, a 12 mm trocar was placed through the Gelport, and the caudate was mobilized from the inferior vena cava (IVC) under laparoscopic view (Fig. 1b). The short hepatic vein from the caudate was preserved if it measured more than 5 mm in diameter. The Arantius duct was transected, and the left and middle hepatic veins were mobilized from the IVC as far as possible. For left lobectomy with or without the caudate lobe, the right triangular ligament was dissected and the right lobe was mobilized with the hand-assisted laparoscopic surgery (HALS) technique. Dissection between the right adrenal gland and the liver was not necessary. Under the hybrid procedure, dissection around the right hepatic vein and pericaval region was carefully performed until the right lobe was fully mobilized. Pneumoperitoneum was ended after checking hemostasis. For left lobectomy, the incision was extended to 10–12 cm, then a retractor was placed. Dissection around the right hepatic vein was performed under direct vision at this point [17]. Cholecystectomy, hilar dissection, the liver hanging maneuver, and liver parenchymal dissection were performed under direct vision through the small midline incision in LADH. We applied the same procedure as that in the open technique in terms of not using any metal clips or inflow occlusion, with minimal dissection of the liver hilum.

Postoperative management and care

A drain was placed at the end of the operation, and was removed on postoperative day 2–3. Postoperative pain control was initiated immediately after operation with intravenous continuous fentanyl infusion at 0.5 μ/kg per hour for 40 h. Donors could receive bolus doses of fentanyl at 0.5 μ/kg per bolus every hour, as needed, up to 40 h after the operation, and flurbiprofen 50 mg or loxoprofen 50 mg thereafter.

Enhanced MDCT was performed on postoperative days (POD) 7, 14, and 28, and at 3, 6, and 12 months after operation. Doppler ultrasonography was performed on POD 1 to rule out the presence of a thrombus in the hepatic artery or portal vein. Donors were considered to be ready for discharge from the hospital on treatment with an oral proton pump inhibitor when the liver function tests were normal or improving satisfactorily, and they were capable of eating sufficient oral intake (more than 80 % of normal adult food).

Postoperative morbidities and evaluation of the health-related QOL after donor surgery

Postoperative morbidities were evaluated based on the Clavien–Dindo classification [18, 19]. Health-related QOL was evaluated preoperatively and at 1, 3, 6, and 12 months after the surgery with the Short Form-36, version 2 (SF36-v2) questionnaire [20].

Assessment of potential difficulty in left-lobe laparoscopy-assisted hybrid donor hepatectomy

Laparoscopy-assisted hybrid donor hepatectomy (LADH) could be more difficult to perform in obese or big male donors. Preoperatively, we calculated the distance between the abdominal wall and the front of the spine at the level of

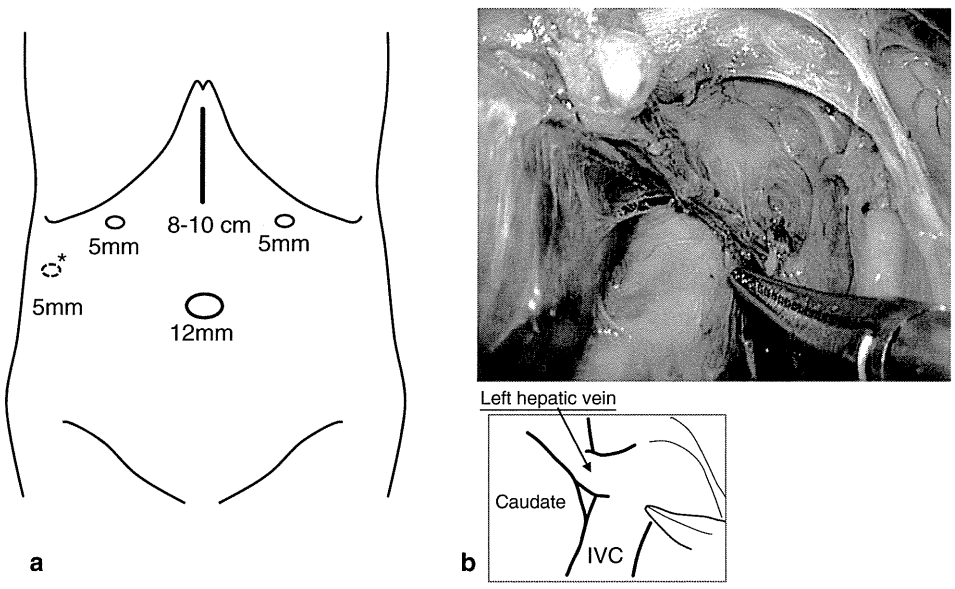

Fig. 1 Laparoscopy-assisted hybrid donor surgery. **a** Skin incision and trocar sites. An upper abdominal midline incision was made over a length of 7–8 cm for left lateral sectionectomy and a length of 10–12 cm for left lobectomy. A 12 mm trocar was placed through the umbilicus, and 2 trocars (5 mm) were placed in the hypochondriac region of either side. A third trocar (5 mm, *) was placed in the right flank for left lobectomy. **b** Mobilization of the left liver plus caudate. The Spiegel lobe of the caudate was completely mobilized under laparoscopic guidance

the portal bifurcation (WS distance), and the maximal distance between the surface of the right lobe and the portal vein bifurcation (RPv distance) on donor CT scans (Fig. 2a, b).

Evaluation of the feasibility and safety of laparoscopy-assisted hybrid donor liver surgery

Living donors who underwent LADH were divided into groups: those who underwent left lateral sectionectomy (LADH-lateral group) and those who underwent left lobectomy with or without the caudate lobe (LADH-left group). Living donors who underwent open donor hepatectomy were also divided into groups: those who underwent left lateral sectionectomy (open donor hepatectomy [ODH]-lateral group) and those who underwent left lobectomy with or without the caudate lobe (ODH-left group).

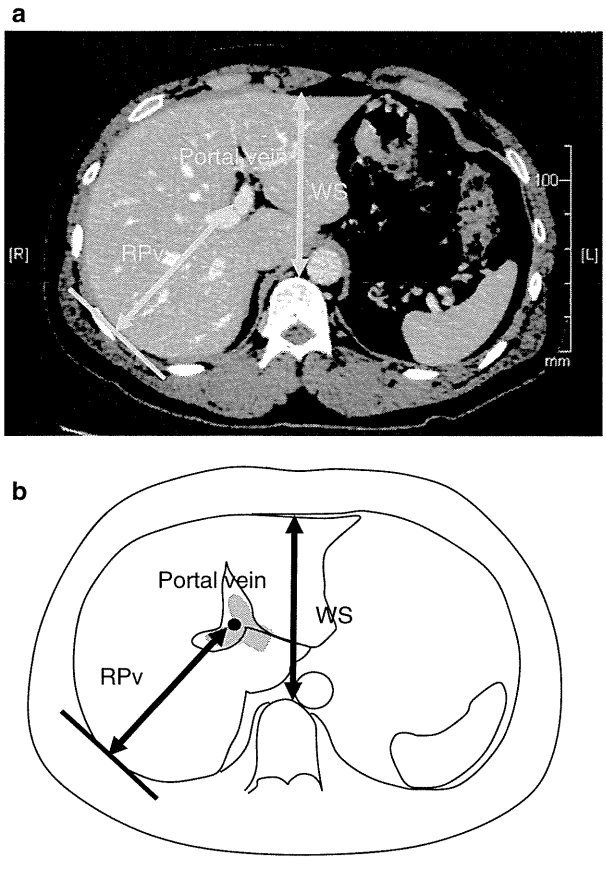

Fig. 2 Distance between the abdominal wall and the front of the spine at the level of the portal bifurcation (*WS distance*) and RPv distance. WS distance was defined as the distance between the abdominal wall and the front of the spine at the level of the portal bifurcation, and the maximal distance between the surface of the right lobe and the portal vein bifurcation (*RPv distance*) was defined as the maximal distance between the surface of the right lobe and the portal vein bifurcation on preoperative CT scans. **a** CT scan image. **b** Schematic view

The demographic characteristics, operative parameters, postoperative morbidities, results of the SF36-v2 questionnaire evaluation, analgesic requirement, and serum C-reactive protein levels measured preoperatively and on POD 1, 3, 7, and 14 were compared between the ODH and LADH groups.

The analgesic requirement was compared between the LADH ($n = 31$) and recent open donor groups (after July 2009 [$n = 21$]), when we stopped using epidural anesthesia and started to use intravenous fentanyl for 40 h after surgery in July 2009.

Statistical analysis

Results are expressed as mean ± standard deviation. Statistical examination of the correlations was based on the Pearson product-moment correlation. Clinical data of the donors were compared with Student's t test. P values <0.05 were considered to indicate statistical significance.

Results

A total of 31 consecutive live liver donors of left-side liver grafts underwent LADH between April 2009 and March 2012; of these, 17 donors underwent left lateral sectionectomy (LADH-lateral group), including one case of in situ S3 monosegmentectomy, and 14 donors underwent left lobe resection with or without the caudate lobe (LADH-left group). We compared the clinical outcomes between the LADH group ($n = 31$) and donors who had undergone open donor hepatectomy (ODH group; $n = 79$) prior to this period in our hospital, which were either open left lateral sectionectomy (ODH-lateral group; $n = 32$), including one case of reduced-left lateral sectionectomy or open left lobe resection with or without the caudate lobe (ODH-left group; $n = 47$).

There was no perioperative or postoperative mortality in any of the donor groups, and all the donors were healthy without any sustained physical or mental problems at 13.9 ± 9.8 months after the donor hepatectomy.

The demographic characteristics of the donors were similar between the LADH group and the ODH group (Table 1). The length of the midline incision was 7.5 ± 0.7 cm in the LADH-lateral group and 10.5 ± 1.4 cm in the LADH-left group. The operative time was 375 ± 65 min in the LADH-lateral group and 508 ± 94 min in the LADH-left group; the operative time was significantly longer in the LADH-left group than in the ODH-left group ($P < 0.001$). The volume of blood loss was similar between the LADH and ODH groups. The

postoperative length of hospital stay was 9.0 ± 2.3 days in the LADH-lateral group and 11.5 ± 3.6 days in the LADH-left group, which were significantly shorter than those for the donors who had undergone open surgery ($P = 0.019$).

The operative time was similar between the donors who underwent left lobe resection with the caudate ($n = 6$) or without the caudate lobe ($n = 8$), and it was not associated with the body mass index (BMI) or the WS distance. Of note, the operative time increased as the RPv distance increased ($P = 0.014$, $r = 0.637$) (Fig. 3a, b). The operative time was significantly longer in the donors with an RPv distance equal to >10 cm ($n = 6$) as compared with donors with an RPv distance of less than 10 cm ($n = 8$) ($P = 0.007$) (Fig. 3c). No significant correlation was observed between the volume of blood loss and the RPv distance or WS distance.

Laparoscopy-assisted hybrid donor hepatectomy was feasible, without any need for conversion to open surgery, in all patients in the LADH group. During the laparoscopic procedure, two incidental injuries (one to the diaphragm and one to the right hepatic vein) occurring during mobilization of the right lobe were successfully managed by finger compression under the HALS technique and subsequent suturing under direct vision through the midline incision. In one of the patients, however, elongation of the midline incision to 15 cm was necessitated; in the other, the procedure was completed through the planned 12 cm midline incision.

Table 1 Characteristics of the laparoscopy-assisted hybrid donor hepatectomy (LADH) group and the open donor hepatectomy (ODH) group

	LADH ($n = 31$)	ODH ($n = 79$)	P value
Age, years	35.8 ± 8.4	37.8 ± 10.1	0.369
Gender (male)	13 (41.9 %)	54 (68.4 %)	0.011
Body mass index (BMI), kg/m^2	21.3 ± 3.6	22.6 ± 3.1	0.075
Type of resection			
Left lateral section (LLS)	16	31	0.174
Reduced left lateral section (rLLS)	1	1	(Left vs. LLS)
Left lobe without caudate (left)	8	10	
Left lobe with caudate (left-C)	6	37	
Operative time, min	435 ± 103	383 ± 73	0.005
Estimated blood loss, ml	353 ± 396	456 ± 347	0.197
Length of hospital stay after surgery, days	10.3 ± 3.3	18.3 ± 16.7	0.019
Complication (Clavien–Dindo grade)			
1	1 (3.2 %)	7 (8.9 %)	0.653
2	0	1 (1.3 %)	
3a	2 (6.5 %)	8 (10.1 %)	
3b	0	1 (1.3 %)	
4/5	0	0	

After the donor surgery the amount of pain medication needed up until the seventh POD after 40 h of systemic fentanyl infusion was compared between the LADH group ($n = 31$) and the recent ODH group ($n = 21$), and was found to be similar between the two groups (Fig. 4a). Likewise, the serum C-reactive protein (CRP) levels after surgery were similar between the LADH and recent ODH group (Fig. 4b).

Postoperative morbidity, defined with the Clavien–Dindo classification [18], was established as grade ≥2 in two donors (6.7 %) with delayed gastric emptying which required fiberoptic endoscopy ($n = 2$) for correcting rotation of the stomach, and both recovered within 2 weeks after the donor surgery. No bile leak or other morbidity was observed.

There was no mortality related to the LADH procedure among the graft recipients. The graft survival rate of the 17 pediatric recipients who received the left lateral section grafts from the LADH-lateral group was similar to that of the 32 pediatric recipients who received the left lateral section grafts from the ODH-lateral group ($P = 0.877$, log rank test) (Fig. 5a). The graft survival rate of the 14 recipients (9 adults and 5 children) who received the left lobe grafts in the LADH-left group was slightly better but statistically similar to that of the 47 recipients (32 adults and 15 children) who received the left lobe grafts in the ODH-left group ($P = 0.237$, log rank test) (Fig. 5b).

A total of 29 donors from the LADH group could be evaluated by the SF36-v2 questionnaire. Comparison with the preoperative test results revealed that the scores for all six components decreased significantly at 1 month after the surgery; thereafter, the physical functioning (PF) score, general health perception (GH) score, vitality (VT) score, social functioning (SF) score, and mental health (MH) score recovered by 3 months, while the role physical (RP) score, bodily pain (BP) score, and role emotional (RE) score recovered by 6 months after the surgery. The PCS score, which was decreased at 1 month after the surgery, recovered by 6 months, and the mental component summary (MCS) score, which was decreased at 1 month after the surgery, recovered by 3 months (Fig. 6).

Discussion

Despite close attention being paid to preventing donor mortality and morbidity in living donor hepatectomies, it is inevitable to encounter them at a certain incidence.

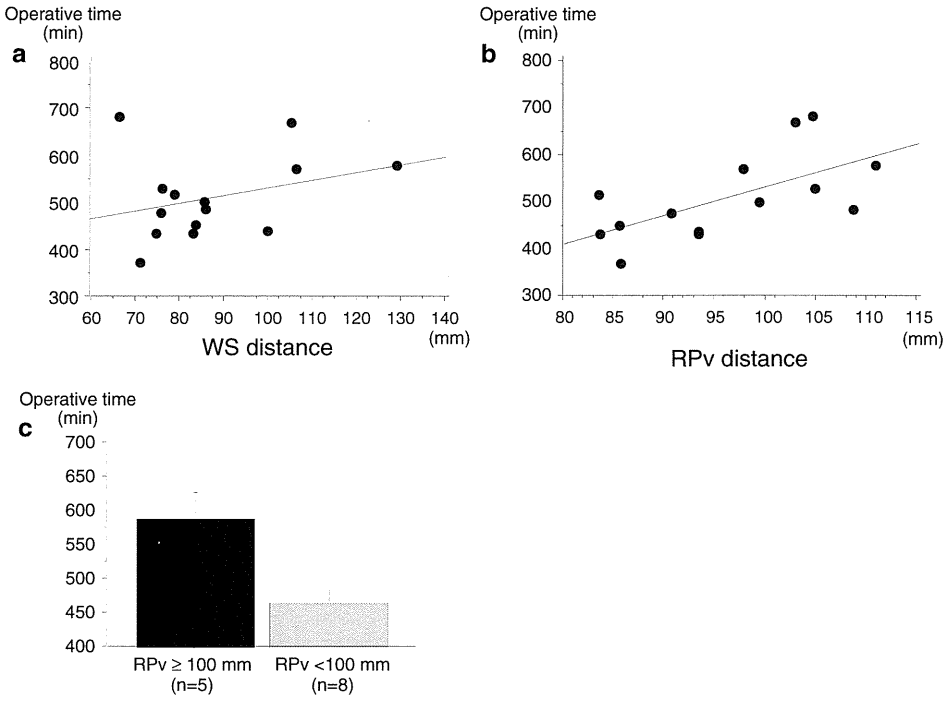

Fig. 3 Relationship between the WS distance and RPv distance and the operative time in the LADH-left group ($n = 14$). **a** WS distance and operative time. There was no significant correlation between these two parameters. ($r = 0.239$). **b** RPv distance and operative time. There was a significant correlation between the RPv distance and the operative time; operative time (min) $= -76.4 + 6.10 \times$ RPv (mm); $P = 0.014$, $r = 0.637$. **c** The operative time was significantly longer in donors with an RPv distance equal to or >10 cm ($n = 6$) than in those with an RPv distance of <10 cm ($n = 8$) ($P = 0.007$)

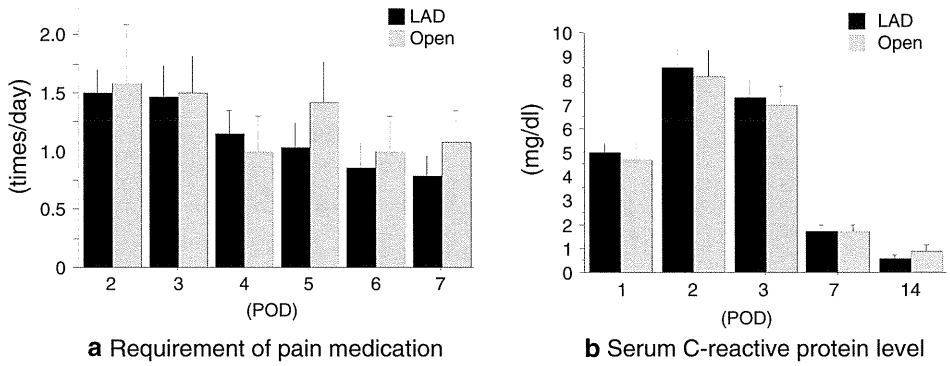

Fig. 4 Analgesic agent requirement and serum C-reactive protein level. (LADH: $n = 31$, ODH group: $n = 21$). **a** Analgesic agent requirement from postoperative day (POD) 2 to POD 7. While the requirement was higher in the ODH group after POD 5, there was no significant difference between the LADH and ODH groups. **b** The serum CRP level peaked on POD 2 in both groups, with no significant difference in the level change between the LADH and ODH groups

Therefore many surgeons consider that the traditional open donor hepatectomy with a big incision is appropriate, merely for reasons of safety. In addition, donor protection is very important in terms of reduction of physical and mental stresses, and also provision of support for recovery from the surgery to a healthy daily life as before the operation. Laparoscopic surgery was introduced in the field of donor hepatectomy, first from left lateral sectionectomy [6] and on to right lobectomy [17], and these techniques have been rapidly spread worldwide. However, parenchymal dissection in laparoscopic view is not always a familiar technique to most hepatobiliary surgeons who are experts in open donor hepatectomies. LADH has been developed based on its advantageous characteristics of less invasiveness for living liver donors and the familiarity of direct parenchymal dissection to hepatobiliary surgeons. One of the other important features of this procedure is the safety we have observed during laparoscopic surgery because of the advantages of hand-assisted surgery.

In our series there were two significant complications during right lobe mobilization: a right diaphragmatic injury and an injury to the right hepatic vein. In each case the surgeon was able to make a successful recovery, initially using fingers in the hand-assisted technique, without any

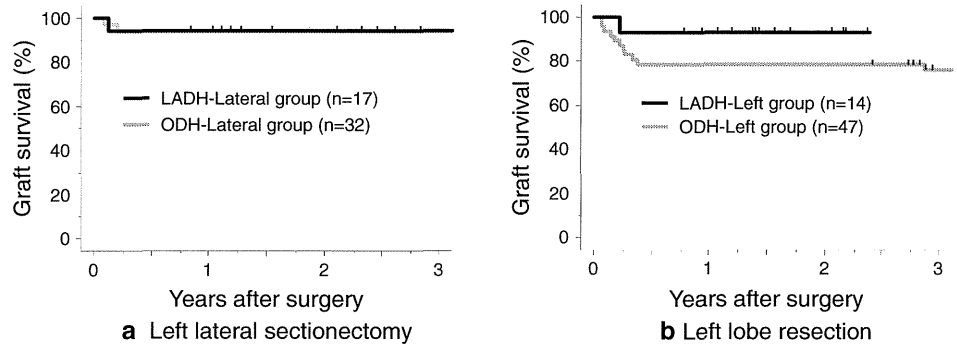

Fig. 5 The graft survival rates after liver transplantation. **a** Left lateral sectionectomy. The graft survival rates were similar between the LADH and the ODH groups ($P = 0.877$, log rank test). **b** Left lobe resection with caudate or without caudate. The graft survival rate in the LADH group was slightly better than that of the ODH group, although there was no significant difference between the LADH and the ODH groups ($P = 0.237$, log rank test)

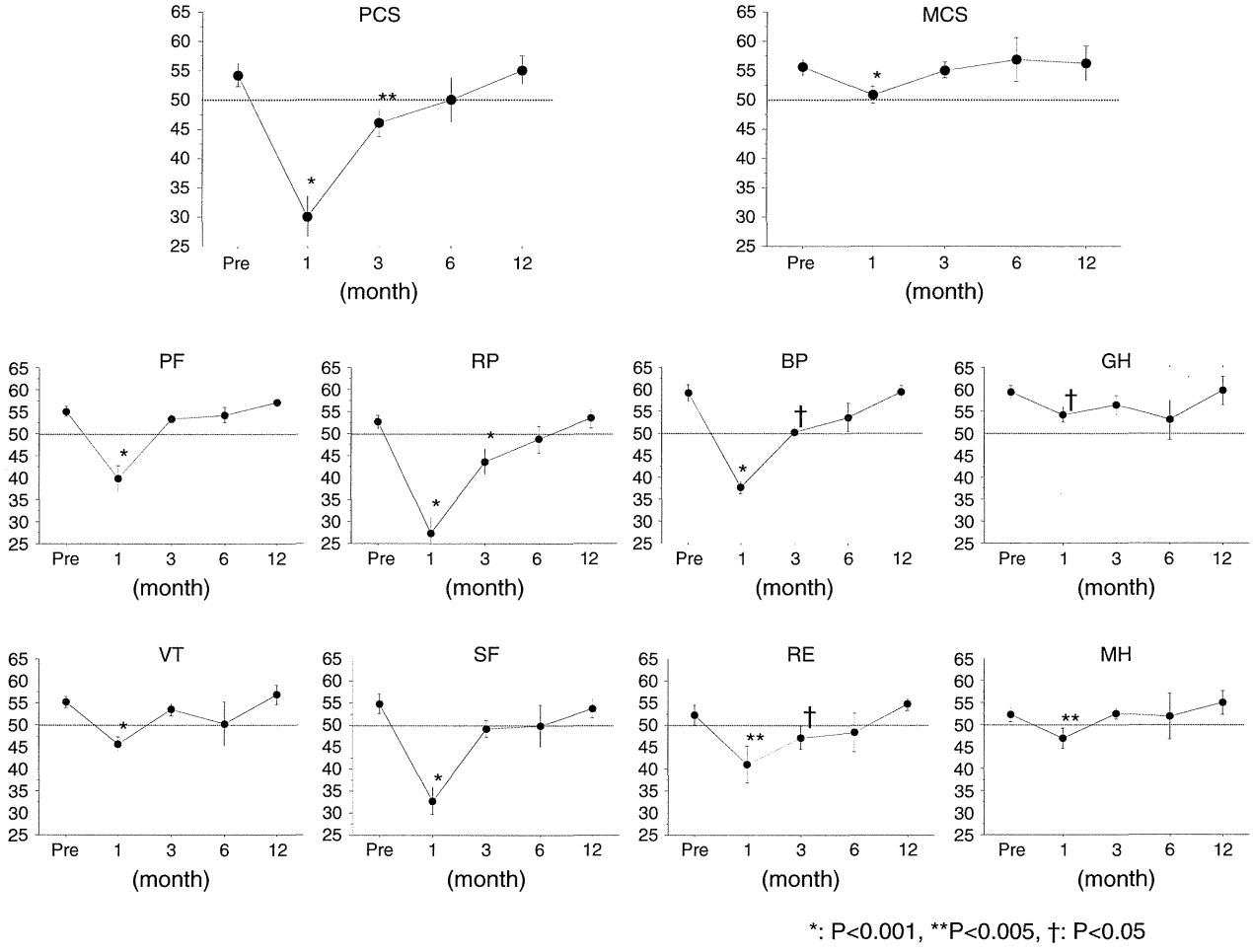

Fig. 6 Evaluation by the Short Form-36, version 2 (SF36-v2) questionnaire. *PCS* physical component summary, *MCS* mental component summary, *PF* physical functioning, *RP* role physical, *BP* bodily pain, *GH* general health perceptions, *VT* vitality, *SF* social functioning, *RE* role emotional, *MH* mental health. * $P < 0.001$; ** $P < 0.005$; † $P < 0.05$

problem under HALS technique. Nevertheless, the safety and efficacy of LADH has not been established, and few feasibility studies are reported [7, 9–11]. Therefore, the purpose of the present study was to investigate the safety and efficacy of the laparoscopic procedure for procuring left liver grafts.

The technique of LADH is quite demanding, and adequate experience with both open donor hepatectomy and laparoscopic mobilization of the left and right hemi-liver is required. Thus, it is important to ensure that LADH is performed by surgeons with adequate experience in both donor hepatectomy and laparoscopic liver mobilization, under the assumption that "experienced" surgeons in donor hepatectomy would be able to perform donor left lobectomy with the caudate by themselves without any supervision.

We have reported the adequacy of our open donor hepatectomy previously, and have also performed laparoscopic hepatectomies very actively. Having established these two bases, we started to perform LADH in a stepwise manner, from LADH-lateral to LADH-left surgery; we believe that this stepwise approach was fundamental from the point of view of preserving the donor safety. We conducted research to determine the best sites for ports, the number of ports, the method for dissecting the liver hilum and hepatic veins in 10 cases of laparoscopy-assisted hybrid left lateral sectionectomy, and then proceeded to left lobe surgery with or without the caudate.

The target length of the midline incision was 7–8 cm for LADH-lateral in our series. This was sufficient to perform hilar dissection and dissection of the liver parenchyma for lateral segmentectomy. For left lobectomy, the incision was extended to 10 cm or longer to ensure an adequate view of the liver parenchyma for dissection. Thus, the mean length of the midline incision was 7.5 ± 0.7 cm for left lateral sectionectomy and 10.5 ± 1.4 cm for left lobectomy. It is noteworthy that the length of the skin incision was uniform in spite of differences in body constitution or BMI in LADH, which could not be expected in open donor hepatectomy.

In our series blood loss was similar between the LADH and ODH groups. The operative time for left lateral sectionectomy was similar between the LADH and ODH groups, but that for left lobectomy was much longer in the LADH group than in the ODH group ($P < 0.001$). No improvement was seen even with case experience (data not shown), suggesting that the longer operative time for left lobectomy was needed because of the small incision in the LADH group.

The operative time in the LADH-left group was associated with the RPv distance, but not with the WS distance. An RPv distance of over 10 cm was identified as a significant risk factor for a prolonged operative time. At first, in fact, we hypothesized that the WS distance might influence the difficulty level of left-lobe LADH. However, no correlation was noted between the WS distance and the duration of operation. We then calculated the RPv distance, because we thought that the difficult cases tended to have a larger right lobe. During the left-lobe LADH procedure, the right lobe is mobilized and rotated toward the midline incision to allow performance of hybrid surgery through the small midline incision. Our results showed that the longer the RPv distance, the longer the duration of left-lobe LADH, suggesting that the volume of the right lobe of the liver had a greater impact on this procedure than the depth of the abdomen. Because left-lobe LADH is expected to be more difficult and to take a longer time in donors with an RPv distance >10 cm in left-lobe LADH, the operation type and explanations to the donors should be carefully conducted preoperatively.

Again in our series, two incidental events occurred during LADH that may have been avoided by a surgeon with greater experience in laparoscopic right lobe mobilization. However, both incidental injuries were easily treated with the help of a hand inserted into the abdomen, which is the one of the advantages of the HALS technique. In case of unexpected incidents such as these, the HALS technique is quite useful and safer than pure laparoscopic surgery, which is one of the reasons why we adopted HALS. It is fundamental in donor surgery not to expose the donor to any avoidable danger.

Postoperative morbidity was rather rare in the LADH group, and the length of hospital stay after surgery was shorter in the LADH group than that in the ODH group ($P = 0.028$), indicating that the safety of the procedure was comparable to that of the well-established open procedure. Serum CRP level is one of the markers of acute-phase reactions to surgery; however, in the present series it failed to reflect any advantage of the laparoscopic procedure, with the smaller skin incision, over the open procedure. In studies comparing open and laparoscopic colorectal surgery, no significant differences in the serum levels of interleukin (IL)-1, IL-6, IL-8, or interferon γ (IFN-γ), all of which are known to be acute-phase cytokines, were found between the laparoscopic surgery and open surgery groups [21]. These results showed that the invasiveness of the surgery was not different between the open and laparoscopic techniques, at least as evaluated by measurements of the serum cytokine levels, even though the patients in the LADH group recovered more rapidly after surgery and discharge than those of the ODH group.

The length of hospital stay after surgery was significantly reduced in the LADH group. Although the length of hospital stay was much longer as compared with that reported from the West in both the open and LADH groups [7], it is our policy to keep the donors in the hospital until the absence of any influence of the surgery in the daily lives of the patients, except for requirement of a minimal amount of pain medications.

In the short-term evaluation, the analgesic requirement during the first week after surgery was similar between the LADH and ODH groups. However, in the longer-term evaluation, the QOL after surgery as evaluated using the SF36-v2

questionnaire showed recovery of both the PCS summary score and the BP pain score by 6 months after operation. Considering the previous report of evaluation of living liver donors by the SF36-v2 questionnaire [20], recovery from bodily pain and physical disturbance after surgery was quicker in the LADH group than in the ODH group. These results showed that LADH may be less invasive and have a positive impact on the postoperative QOL in the donors.

The graft survival rates in the recipient patients, which were fundamental and important in evaluating the outcome of donor hepatectomy, were similar between the LADH group and the ODH group either in left lateral sectionectomy or left lobe resection. The slight difference in the graft survival rates between the LADH-left and the ODH-left groups in left lobe resection was considered to have resulted in part because of the different time periods in which the surgeries had been performed. These results could also strengthen the positive evaluation of the LADH procedure from the standpoint not only of the donors but also the recipients.

This study was not a randomized or high-volume study. Therefore, the results should be interpreted cautiously. Nonetheless, the results suggesting that LADH was safe and feasible, and provided a better QOL after surgery in our series, may justify continuation of LADH for procuring left liver grafts.

One of the problems in our series was that the operative time for procuring a left liver graft with LDAH was significantly longer than that of open surgery. The operative time for left-lobe LADH depends on the duration of open procedures, suggesting that more experience in hilar dissection and parenchymal transection under the hybrid procedure would be important for reducing the operative time. Another approach could be increasing the length of the incision to more than 10 cm, especially in donors with an RPv distance of more than 10 cm.

In conclusion, LADH was safe and feasible for harvesting left liver grafts in the hands of surgeons with experience in both open donor surgery and laparoscopic surgery, and use of the procedure had a positive impact on the postoperative QOL in the donors, although the prolonged duration of the procedure in the LADH-left group needs to be improved with further experience and improvements in the technique of LADH. Left-lobe LADH should be carefully planned in donors with an RPv distance of more than 10 cm, in view of the potential surgical difficulty.

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