Residual liver volume as a predictive value for donor outcome in adult right lobe living donor liver transplant

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Background
Right lobe liver donation is a widely accepted procedure that results in the expansion of the indication for living donor liver transplantation (LDLT). Precise preoperative evaluation of a donor is important for performing LDLT successfully and safely in both the recipient and the donor.
Objective
The aim was to evaluate postoperative donor outcome regarding liver functions and complications after adult right lobe LDLT with different residual liver volumes.
Design
A prospective study was conducted.
Patients and methods
Between September 2014 and April 2016, we prospectively compared 41 donors having a remnant liver volume (RLV) of 35–40% (group A) with 42 donors having a RLV of 41–49% (group B) for donor outcomes. All the complications in donors were systematically classified.
Results
Donors of the group A showed significantly higher peak international normalized ratio and bilirubin levels and lower albumin level than group B. The incidence of postoperative complications was seen in 15 (36.6%) patients in group A and in nine (21.4%) patients in group B. The overall incidence of complications was 28.9%.
Conclusion
The use of donors with more than 35% RLV is safe regarding the postoperative donor outcome. The use of donors with less than 35% RLV is controversial, so, we recommend more advanced studies on lower RLV less than 35% to increase pool of potential donors for LDLT, especially in countries in which deceased donor liver transplantation is still forbidden.

Keywords:
donor outcome, liver transplantation, living donor, residual liver volume

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Introduction

Living donor liver transplantation (LDLT) is a successful treatment for patients with end-stage liver disease; this procedure is possible because of the segmental structure of the liver and the regeneration potential of the remnant parts [1].

The underlying driving force for spreading the idea of LDLT is the lack of cadaveric donor livers and the resultant deaths of patients awaiting liver transplants [2]. Regardless of the benefit that LDLT offers to the critically ill patients with end-stage liver disease, donor safety is a prime concern [3].

It is well known that the graft-to-recipient body weight ratio should be at least 0.8% to prevent small-for-size syndrome in the recipient. On the contrary, a large enough left lobe should remain in the donors to meet metabolic demand until the remnant regenerates to a sufficient size [4].

An estimate for donor mortality for LDLT (involving adult or child recipients and any graft type) is ~0.2%, but this may be an underestimate [5].

In the past, several surgeons have documented that the accepted lower safety margin of donor remnant liver volume (RLV) has to be 30% of the total liver volume in LDLT. Transplant surgeons have to set strict limitation for the safety margin of RLVs [6].

Considering the controversy regarding safety and the extent of RLV in right-lobe LDLT, we decided to evaluate postoperative donor outcome regarding liver functions and complications in donors for LDLT with different residual liver volumes (RLVs).

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Patients and methods

Between September 2014 and April 2016, 85 donors underwent right hepatectomy for adult-to-adult LDLT at Ain Shams University Specialized hospital and Egypt Air hospital by a single team. This was a prospective cohort study.

The study population was divided into two groups: group A included 41 donors for LDLT and their RLV was between 35 and 40%, and Group B included 42 donors for LDLT and their RLV was between 41 and 49%.

An additional two donors were dropped from the study owing to intraoperative decision of procedure abortion.

Preoperative evaluation

Inclusion criteria

We selected donors with right lobe graft donation without middle hepatic vein in which RLV ranges from 35 to 49%.

Criteria for donor of living donor liver transplantation

Age must be between 21 and 50 years, except in offspring, where older than 18 years were accepted; BMI must be up to 28; blood group must be compatible; Rh compatibility was not a significant criterion; the donor must be medically free (patients with hyperlipidemia are accepted after correction by medical treatment and changing diet habits), donors should have steatosis in the liver biopsy less than 20%; and the donor must have no history of upper abdominal surgery.

Exclusion criteria

Donors of LDLT having RLV less than 35% or more than 49%, donors with right lobe graft with middle hepatic vein, donors with left lobe graft, and donors with liver biopsy having steatosis greater than 20%, extensive fibrosis (diffuse or peripheral), or active hepatitis, either acute or chronic, were excluded.

The donor operation, possible risks and expected outcome were explained in details to the donor twice, once in the presence of other members of the family and the second time during an interview with the donor in front of the ethical committee to ensure free voluntarism and free of coercion. The donor was reassured that he/she withholds the right to refrain from donation at any time till before the operation.

After fulfilling the general selection criteria, all donors were passed through the following three phases for donor preparation.

(1) Evaluation phase: clinical evaluation and following laboratory assessments: blood group, Rh type, HCV Ab, HBVs Ag, HIV Ab and HBc Ab IgG.
(2) Phase one: biochemical, hematological, and coagulation profile.
(3) Phase two: viral markers, coagulation profile (protein C, protein S, antithrombin III, lupus anticoagulant, anticardiolipin Ab IgM, and anticardiolipin Ab Ig G), tumor markers (CEA, CA 19-9, PSA, CA125, CA 15-3, and α-FP), and circulating Bilharzial Ag if needed.

Imaging procedures

Abdominal duplex ultrasonography, spiral computed tomography (CT) scan, CT of the abdomen, arteriography, portography, and venography were done to assess arterial and venous anatomy and for exclusion of any unrecognized diseases. CT volumetry was done to estimate the volume of the whole liver, right liver volume with or without inclusion of the middle hepatic vein in the graft, and the remaining liver volume. MRCP was done to delineate the biliary anatomy and was compared with intraoperative cholangiography.

Liver biopsy was routinely done in all donors, being the last step of donor evaluation.

Donor surgical procedure

The selected donors were admitted to the hospital one day before the operation and underwent right formal hepatectomy through a J-shaped hockey stick incision, including a small upper midline incision and a right subcostal incision to enter the abdomen.

First, we mobilized the liver and then dissected and isolated the structures at the hepatic hilum. Cholecystectomy and cholangiography through the cystic duct stump for evaluation of the biliary tree were performed. The line of transection was determined by using intraoperative ultrasound. A harmonic scalpel (J&J, New Jersey, USA) and cavitron ultrasonic surgical aspirator (CUSA System 200 macrodissector; Cavitron Surgical Systems, Stamford, Connecticut, USA) were used for parenchymal division. Heparin (5000 units) was given intravenously before the clamping of the right hepatic artery after transection of the parenchyma. The graft was washed after removal followed by immediate flashing through right portal vein by ~3 l of

histidine–tryptophan–ketoglutarate solution on the back table, and then the graft was weighed. After removal of the graft, vessel stumps are closed with continuous, nonabsorbable sutures. The stump of the right biliary duct is closed with interrupted, absorbable 6/0 PDS sutures. Before closure of the abdomen, two silastic drains were placed in the right upper quadrant.

This was the surgical technique done by our center throughout the whole study [7].

Postoperative care

Donors were extubated in the operating room and transferred to the surgical ICU. Pain control was then accomplished with intravenous and/or oral narcotics according to the individual patient's need. Donors were started on ambulation and a clear liquid diet on postoperative day 2. The diet was advanced slowly on postoperative days 3 and 4, and then the donor was transferred to the ward when clinically and hemodynamically stable.

Follow-up

Clinical data included the following:

(1) Vital data including pulse, blood pressure, temperature and respiratory rate to detect any hemodynamic instability and respiratory complications.
(2) Bowel habits.
(3) Drain: amount and color of the drain. Drain was removed when the amount of the drain fluid was less than 50 ml within 24 h.
(4) Wound care: wound discharge would be sent for culture and sensitivity.

Laboratory investigation included the following:

Complete blood picture and serum chemistry, with full liver profile and coagulation profile, were done. Full cultures and sensitivity including blood cultures, sputum, and urine cultures were sent if signs of sepsis occurred. The tip of the drain and central venous line were also cultured after removal.

Radiological

Abdominal duplex ultrasonography was done.

Postoperative complications

Modified Clavien classification was used

It is divided into five grades: group I, deviation from the normal postoperative course, but without the need for therapy; group II, complication requiring pharmacologic treatment; group III, complication with the need for surgical, endoscopic, or radiologic intervention (III a/b, without/with the need for general anesthesia); group IV, life-threatening complication requiring intensive care; and group V, death.

Data collection

Preoperative assessment

This included age, sex, BMI, CT volumetry, including total liver volume and expected RLV (left lobe+MHV), preoperative laboratory tests (liver profile), and liver biopsy.

Operative assessment

This included time of procedure, estimated blood loss, blood transfusion, cell saver recovery, intraoperative actual graft volume, and actual calculated RLV.

Actual RLV=total liver volume (CT volumetric finding)–actual graft volume (operative finding).

Postoperative assessment

This included hospital stay; laboratory findings daily during the first week and then every other day during the second week, and day before discharge (named as day x); the peak values of total bilirubin and international normalization ratio (INR) and the time of these values; the time of return of synthetic liver function to normal via normalization day of INR, albumin, and bilirubin; and follow-up ultrasound duplex every day at first week and then twice weekly till discharge. Postoperative complications (vascular complications, biliary complications, wound infection or dehiscence and intra-abdominal collections), as well as data on whether managed conservatively or need reoperation or intervention were also documented.

Statistical analysis

Data were collected, revised, coded, and entered to the statistical package for the social sciences (IBM SPSS, New York, USA) version 20. Qualitative data were presented as number and percentages whereas quantitative data were presented as mean, SD, and ranges.

The comparison between the two groups with qualitative data was done using χ^2-test, and/or Fisher's exact test was used instead of χ^2-test when the expected count in any cell was found to be less than 5.

The comparison between the two groups regarding quantitative data with parametric distribution was done by using independent *t*-test, whereas comparison between the two paired groups regarding

quantitative data with parametric distribution was done by using paired *t*-test.

Results

The donors included 67 men and 16 women, with a mean age of 28.12±6.4 years for group A and 28.19 ±8.27 years for group B. The demographic data showed no statistical significance, except in sex owing to the randomized different distribution between the two groups (Table 1). There were no significant differences in pre-operative steatosis in liver biopsy between both the groups (Table 2).

The two groups showed statistically significant differences between CT volumetric results and actual liver volumes, with a mean difference of 0.60±0.18 (P =0.002) for group A and a mean difference of −3.17 ±0.47 (P=0.000) for group B.

It is important to indicate that we divided the two groups according to actual RLV not the estimated

Table 1 Demographic and preoperative criteria for donors

	Actual RLV≤40 (N=41)	Actual RLV>40 (N=42)	Independent *t*-test	
			t/χ^{2*}	P value
Age				
Mean±SD	28.12±6.04	28.19±8.27	0.043	0.966
Range	18–40	18–50		
Relativity				
Related	30 (73.6)	33 (78.4)	1.012	0.315
Unrelated	11 (26.4)	9 (21.6)		
Sex				
Female	3 (7.3)	13 (31.0)	7.448*	0.006
Male	38 (92.7)	29 (69.0)		
Smoking				
ex-smoker	1 (2.4)	2 (4.8)	6.206*	0.102
Yes	5 (12.2)	13 (31.0)		
Ex-addiction	0 (0)	1 (2.4)	0.988	0.320
BMI				
Mean±SD	25.17±2.09	24.45±2.21	−1.526	0.131
Range	17–28	20–28.6		
Initial lab				
NAD	41 (100.0)	42 (100.0)	NA*	NA
Past medical condition				
NAD	41 (100.0)	42 (100.0)	NA	NA

RLV, remnant liver volume. *χ^2-test.

Table 2 Operative characteristics in two groups

	Actual RLV≤40 (N=41)	Actual RLV>40 (N=42)	χ^2/t*	P value
Surgical time				
Mean±SD	6.22±0.95	6.08±0.99	−0.638*	0.525
Range	4–8.5	4.5–8		
Range	550–1260	630–1200		
Range	560–1270	600–1025		
Intra operative donor complication				
No	41 (100.0)	42 (100.0)	NA	NA
Blood loss				
Mean±SD	567.07±227.65	445.24±184.06	−2.684*	0.009
Range	100–1200	100–900		
Allogeneic blood transfusion				
No	41 (100.0)	42 (100.0)	NA	NA
Cellsaver recovery				
Mean±SD	425.00±203.81	319.74±134.33	−2.678*	0.009
Range	100–1000	100–700		

RLV, remnant liver volume. *Independent *t*-test.

RLV. There was a donor with an estimated RLV of 38% but had an actual RLV of 48%, so his data were shifted to group B.

Postoperative characteristics

All donors were transferred to the ICU for immediate postoperative care, and then transferred to the ward. There is no statistical difference between the two groups in either ICU or hospital stay (Table 3).

There was no significant difference between the two groups regarding the level of serum albumin. but there was a statistically significant difference regarding the time of normalization of albumin (P=0.01), with mean of 11 days for group A and 9 days for group B, which means that in group A, values were lower, with more time needed for recovery of serum albumin value (Table 4).

Postoperative follow-up showed significantly higher peak total bilirubin and INR levels in group A patients. Patients with a small remnant showed higher postoperative day 7 total bilirubin levels, with significant difference between the two groups regarding the level and day of normalization, but the INR levels returned to normal in both groups. There was no statistical significance regarding INR values or its peak value, and significant difference was only found in the timing for normalization (Tables 5 and 6).

Prolonged hyperbilirubinemia was defined as a total bilirubin level of more than 2 mg/dl by the end of the second postoperative week, which occurred only in group A patients (two patients); at the 1-month follow-up, both patients had normal total bilirubin levels.

There were another two donors in group A who had serum total bilirubin more than 1.5 mg/dl and less than 2 mg/dl on the day of discharge: one of them had RLV 35% and the other had RLV 38%; both patients had normalized bilirubin values after 1 week of discharge.

Postoperative complications

The incidence of postoperative complications was seen in 15 (36.6%) patients in group A and in nine (21.4%) patients in group B. The overall incidence of complications was 28.9%.

According to the classification of postoperative complications for living donors by modified Clavien, all grades of complications occurred, except grades IV and V. The details of those complications and their incidence are listed in Tables 7 and 8. The most common complication was pleural effusion (19.2%) and bile leak (10%).

Table 3 ICU and hospital stay in both groups

	Actual RLV≤40 (N=41)	Actual RLV>40 (N=42)	χ^2/t*	P value
Hospital stay				
Mean±SD	13.44±3.51	13.98±5.15	0.554	0.581
Range	9–22	9–35		
ICU stay				
Mean±SD	2.34±0.69	2.21±0.68	−0.843	0.402
Range	1–3	1–3		

RLV, remnant liver volume. *Independent t-test.

Table 4 Comparison between two groups regarding albumin values progression

	Actual RLV≤40 (N=41)	Actual RLV>40 (N=42)	t	P value
Albumin day 2				
Mean±SD	3.09±0.43	3.05±0.48	−0.400	0.690
Range	2.2–4.1	2.1–3.9		
Albumin day 7				
Mean±SD	3.06±0.50	3.14±0.45	0.783	0.436
Range	2–4.5	2.4–4.8		
Albumin day x				
Mean±SD	3.46±0.49	3.53±0.42	0.749	0.456
Range	2.3–4.5	3–4.2		
Day of normalized albumin				
Mean±SD	11.73±4.44	9.60±2.77	−1.456	0.010
Range	5–30	4–16		

RLV, remnant liver volume.

Table 5 Comparison between two groups regarding total bilirubin values progression

	Actual RLV≤40 (*N*=41)	Actual RLV>40 (*N*=42)	*t*	*P* value
Total bilirubin day 2				
Mean±SD	2.96±1.62	2.04±1.10	–3.032	0.003
Range	0.8–8	0.4–7		
Total bilirubin day 7				
Mean±SD	1.86±1.23	1.06±0.51	–3.859	0.000
Range	0.4–6.2	0.4–2.6		
Total bilirubin day x				
Mean±SD	0.84±0.44	0.57±0.29	–3.365	0.001
Range	0.3–2.5	0.2–1.5		
Peak total bilirubin				
Mean±SD	3.88±1.73	2.83±1.35	–3.105	0.003
Range	0.9–7.6	0.6–7.1		
Day				
Mean±SD	3.10±1.71	2.62±1.25	–1.456	0.149
Range	1–9	1–7		
Day of normalized bilirubin				
Mean±SD	9.22±3.73	6.74±2.52	–1.456	0.001
Range	3–20	2–14		

RLV, remnant liver volume.

Table 6 Comparison between two groups regarding international normalization ratio value progression

	Actual RLV≤40 (*N*=41)	Actual RLV>40 (*N*=42)	Independent *t*-test	*P* value
INR day 2				
Mean±SD	1.72±0.28	1.65±0.30	–1.062	0.291
Range	1.1–2.87	1.1–2.4		
INR day 7				
Mean±SD	1.23±0.19	1.20±0.17	–0.642	0.522
Range	0.95–1.7	0.9–1.7		
INR day x				
Mean±SD	1.06±0.12	1.05±0.10	–0.501	0.618
Range	0.9–1.54	1–1.4		
Peak INR				
Mean±SD	1.81±0.27	1.81±0.43	–0.042	0.967
Range	1.33–2.87	1.2–3.9		
Day				
Mean±SD	2.10±0.66	1.83±0.54	–1.996	0.049
Range	1–4	1–3		

INR, international normalized raio; RLV, remnant liver volume.

Discussion

Adult LDLT has been an important addition to liver transplantation field especially in countries in which organ availability from brain-dead patients has been prohibited by law.

Precise preoperative evaluation of a donor is critical for performing LDLT successfully and safely in both the recipient and donor. Yaprak *et al.* [8] stated that RLV to total liver volume ratio is predictive of postoperative adverse effects on donor.

Liver biopsy was routinely done in our study owing to the high prevalence of fatty liver among the Egyptian. Poor graft function and risk of overall graft failure have been reported with the use of steatotic grafts in LDLT [9]. Therefore, most centers, including the present, limit the acceptance of donors with liver steatosis more than 20% [10]. The study by Siriwardana *et al.* [11] which was conducted on 325 liver donors, concluded that using a liver graft with up to 20% steatosis in liver donation is safe, with no significant difference between the groups regarding postoperative liver function tests and postoperative complications.

Surprisingly, we also found that some potential donors with normal BMI had a high percentage of liver steatosis; some of them were discovered intraoperatively, with normal preoperative biopsy result. This occurred in one donor, who was excluded from the study owing to

Table 7 Postoperative complications in the two groups

	Actual RLV≤40 (*N*=41)	Actual RLV>40 (*N*=42)	χ^2/t^*	*P* value
Pleural effusion	8 (19.2)	8 (19.2)	0.00	0.982
Bile leakage	5(12)	3 (7.2)	0.608	0.436
Abdominal collection	4 (9.6)	3(7.2)	1.867	0.172
Mean±SD	97.78±80.28	126.67±126.91	–1.456*	0.596
Range	100–300	100–350		
Pigtail application related to abdominal collection	1 (25)	1 (33)	0.128	0.893
Suspected pulmonary embolism				
CT angiography negative	1 (2.4)	3 (7.1)	1.001	0.317
Wound infection	1 (2.4)	1 (2.4)	0.000	0.986
Pancreatitis	1 (2.4)	0 (0.0)	1.037	0.309
Fever	2 (4.8)	1 (2.4)	0.988	0.320
Doppler abnormality	1 (2.4)	0 (0)	0.988	0.320
Postoperative bleeding	0 (0.0)	3 (7.1)	3.038	0.081
Gastroenteritis	0 (0.0)	1 (2.4)		
Reoperation	0 (0.0)	1 (2.4)	0.988	0.320
UTI	0 (0.0)	0 (0.0)	NA	NA
Biliary stricture	0 (0.0)	0 (0.0)	NA	NA
Massive ascites	0 (0.0)	0 (0.0)	NA	NA
PVT	0 (0.0)	0 (0.0)	NA	NA
Pneumonia	0 (0.0)	0 (0.0)	NA	NA

CT, computed tomography; PVT, portal vein thrombosis; RLV, remnant liver volume; UTI, urinary tract infection. *Independent *t*-test.

Table 8 Postoperative complications according to modified-Clavien classification

Complications	Group A (35–40%)	Group B (41–49%)	Management
Grade I			
Fever	2 (4.8)	1 (2.4)	Antipyretics
Minor bile leak from drain	5 (12)	3 (7.2)	Spontaneous stoppage
Grade II			
Minor postoperative bleeding	No	3 (7.2)	Two donors stabilized with allogenic transfusion of blood
Wound infection	1 (2.4)	No	Wound drainage and antibiotics after culture and sensitivity
Plural effusion	8 (19.2)	8 (19.2)	
Abdominal collection in US	4 (9.6)	3 (7.2)	Conservative
Pneumonia	No	No	Antibiotics
Urinary tract infection	No	No	Antibiotics
Acute pancreatitis	1 (2.4)	No	Conservative medical treatment
Grade IIIA			
Bile leak	No	No	
Biliary strictures	No	No	.
Pleural effusion	0	1 (2.4)	Percutaneous US guided aspiration
Intra-abdominal collection	1 (2.4)	1 (2.4)	Pigtail aspiration
Grade IIIB			
Bleeding	0	1 (2.4)	
Grade IV	0	0	
Grade V	0	0	
Total	36.6	21.4	

US, ultrasound.

intraoperative decision of procedure abortion, after intraoperative liver biopsy, which revealed severe steatosis; another dropout was because of an unexpected event regarding the recipient.

We found a highly significant statistical difference between calculated RLV by CT volumetry and actual RLV in all patients and in the two groups separately. We thought that graft volumes estimated by preoperative imaging were higher than intraoperative graft weights, primarily owing to the weight of blood *in vivo*, Imaged volume exceeded measured weight by a mean of 145 g for group A and 106.6 g for group B.

Blood loss and cell-saver recovery were significantly higher in group A. The mean operative time showed no difference. Intraoperative blood loss was higher in our study, with 567.07±227.65 in group A and 445.24

±184.06 in group B, whereas in the study by Taner *et al.* [1] it was 360±230 in group 1 and 310±70 in group 2; this may be also owing to the slightly larger grafts in our study (Figs 1–3).

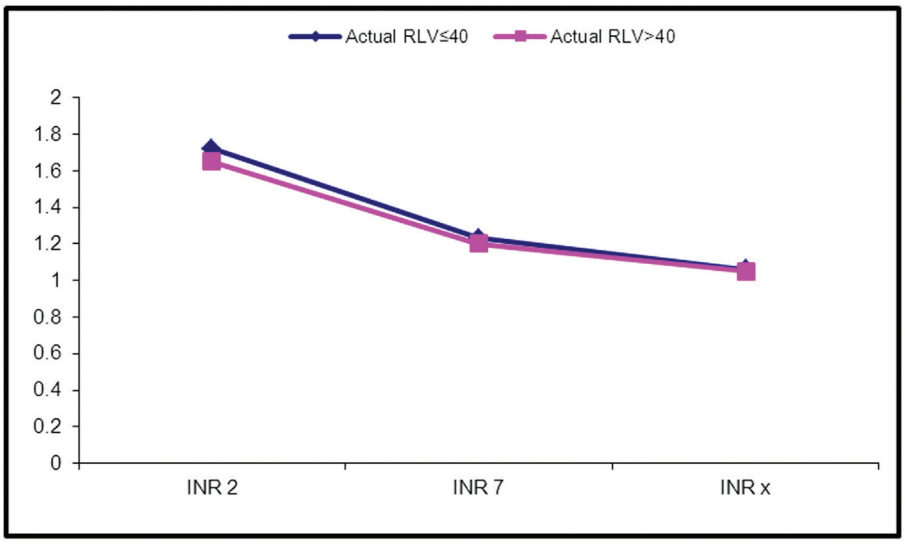
Postoperatively, group A showed significantly higher peak bilirubin and more sustained levels, and highly significant difference in the time needed for its normalization. INR values showed no significant differences, with slightly little increase in time needed for normalization of INR in group A.

Cho *et al.* [12] compared two groups regarding RLV, where group 1 had greater than 35% and group 2 had less than 35%, and found no significant difference regarding postoperative laboratory results, except for higher peak bilirubin in group 2 and transient sustained hyperbilirubinemia, which regressed in 1 month; no significant differences regarding serum albumin were found.

These values are better than the values obtained by Taner *et al.* [1] in which peak total bilirubin varied from 4.5±2.3 in group 1 and 6.3±3.4 in group 2, with peak INR showing statistically significant difference, which was 1.7±0.1 for group 1 and 1.9±0.1 for group 2. In our study, both groups had nearly the same mean of 1.8 in peak bilirubin level.

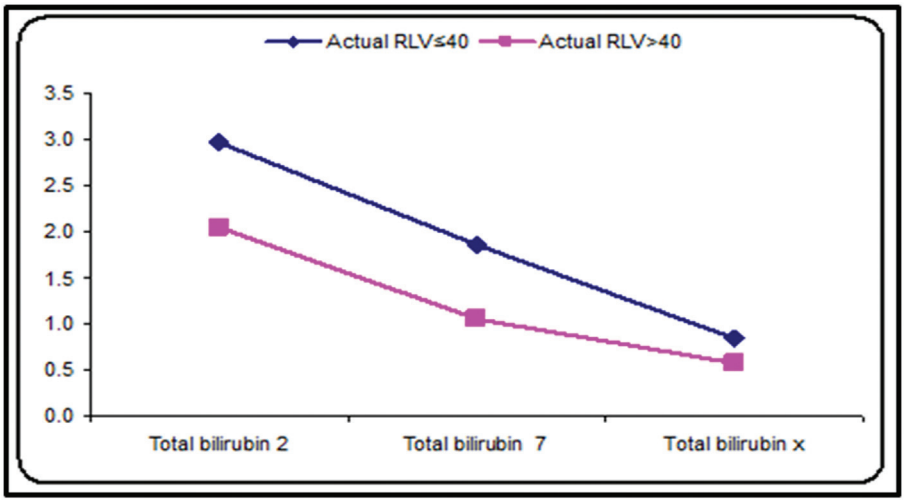
Reichman *et al.* [13] found that the extent of the liver resection significantly correlated with the peak INR,

Figure 1



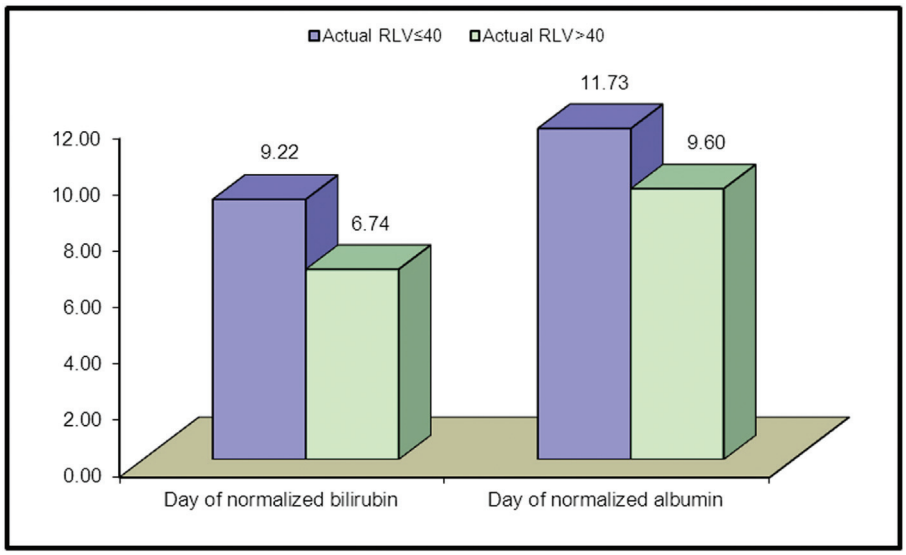
Comparison between two groups regarding international normalization ratio.

Figure 2



Comparison between two groups regarding total bilirubin progression.

Figure 3



Comparison between two groups regarding day of normalized bilirubin and albumin.

the days to INR normalization, and the peak bilirubin level.

Serum albumin values showed differences between the two groups, as in group A, serum albumin showed slightly lower ranges, with more time to recover than group B, which reflects the effect of RLV on liver synthetic function. Better results may be because of the reflection of our increasingly strict policy to exclude donors with liver biopsy done routinely showing macrovesicular steatosis more than 20% with RLV not less than 35%.

Regarding the complication rate in our study, the overall complication rate was 28.9%, (36% in group A and 21% in group B). We did not find statistically different rate of complication or direct relationship among both groups of the study; moreover, we found no correlation between grade III complications and RLV. This is similar to the study by Cho *et al.* [12] who found no statistically significant differences regarding complication rates in both study groups.

Reichman *et al.* [13] demonstrated that hepatectomy, the spared volume percentage, and the peak bilirubin level were strongly associated with grade 3 complications. A higher peak bilirubin level, which correlated with a lower RLV, was associated with grade 3 complications in a multivariate analysis.

In addition, Meng *et al.* [14] performed a retrospective study on 151 LDLT donors who were classified according to the RLV, and the incidence rates of severe complications (Clavien III) of the 3 groups (RLV <35%, 35–40%, and >40%) were significantly different (21, 15, and 6%, respectively).

The same was found by the study of Taner *et al.* [1] which revealed that donors with a RLV less than 30% had a four times greater relative risk of morbidity (P=0.043).

Our complication rates were much less than Sun *et al.* [15] who retrospectively identified and evaluated the postoperative complications as per the modified Clavien classification system in 152 living liver donors at the First Affiliated Hospital, College of Medicine, Zhejiang University between December, 2006 and June, 2014. Postoperative complications were observed in 61 (40.1%) patients.

The most common complication in our study was pleural effusion with equal rate between the two groups (19.2%). All except one donor had grade I complication, and all of them were managed conservatively with antibiotics and chest exercises, which improved spontaneously. The only grade III complication was in group B and was managed via pleurocentesis. This is similar to the study by Sun *et al.* [15] in which the most frequently encountered morbidity was mild pleural effusion (n=25, 16.4%) and was generally automatically absorbed; however, pleural effusions in six donors were treated with pleurocan insertion and drainage, and pneumothorax in one patient was treated with chest tube.

Biliary leakage in our study occurred in 10% of patients, and all were grade I complications, which were

managed conservatively. This result was better than a previous study for the same center by El-Meteni *et al.* [16], between November 2001 and December 2008, where 207 adult-to-adult ALDLT were undertaken using right lobe graft. The overall biliary complications occurred in 27 (13%) cases, and there were grades II, III, and V biliary complications.

The improvement may have occurred owing to having gained more experience, developed handling of tissues, more perfection of techniques, precise biliary anatomy, and meticulous hilar dissection.

Regarding acute pancreatitis in the only donor (1.2% of all donors and 2.4% of group A.) was thought to be owing to the intraoperative cholangiogram and was managed conservatively, where diluted dye in saline by ratio of 1/1 was then used.

No cases of urinary tract infection (UTI) and DVT were found; the low infection rate in our study was mostly owing to strict infection control instructions intraoperatively and postoperatively.

No cases of portal vein thrombosis (PVT) were found. This may be because of meticulous dissection of liver pedicle, leaving sufficient portal stump for donor and closure of PV via continuous proline 6/0 suture to avoid stricture of portal confluence. In contrast, there was one case of PVT in the study by Taner *et al.* [1] which did not recommend postoperative routine anticoagulation.

We had two donors with postoperative bleeding, but they were managed conservatively with blood transfusion, mostly owing to elevated INR. Reoperation for bleeding was done in one (1.2%) donor only, and he was from group B.

There was no donor mortality in our study. However, there are currently at least 19 donors who have died of postoperative complications worldwide; most were right lobe donors, with a rough estimate of donor mortality at 0.2–0.5%. In addition, one donor entered a vegetative state and 3 donors had to receive liver transplantations themselves [13].

In the study by Azzam *et al.* [17] the only donor mortality in this study was owing to liver failure because of a small remnant liver (26%). Although there was steatohepatitis diagnosed postoperatively, it is not sufficient alone to produce severe hepatic dysfunction; the cornerstone was the small RLV, which was because of insufficient volumetry results.

Conclusion

RLV is a key factor affecting donor recovery and safety. The use of donors with more than 35% RLV is safe regarding the postoperative donor outcome. In our study, we found that using donors with RLV more than 40% was favorable in terms of liver recovery.

Recommendation

More studies should be conducted to assess the safety and outcome of donors with RLV less than 35%.

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Conflicts of interest

There are no conflicts of interest.

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