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Original Article

Laparoscopic or abdominal left extrahepatic lobectomy of donor liver in pediatric living donor liver transplantation: a report of 17 cases

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Abstract: Background and objectives: The aim of this study was to compare outcomes from laparoscopic and abdominal left lateral hepatectomy of donor livers during pediatric living donor liver transplantation (LDLT), and to summarize the key points for laparoscopic living donor liver hepatectomy as well as its prospects for wide application. Methods: Clinical data from 17 donor-recipient pairs of abdominal pediatric LDLT or laparoscopic pediatric LDLT were collected from the General Hospital of Chinese Armed Police Force, and the perioperative clinical parameters as well as the postoperative prognoses of the two groups were compared and analyzed. Results: There were no complications observed in the operation with all 17 pairs. In the laparoscopy group, the length of postoperative hospitalization was 3-4 d, average length of hospitalization 3.50 ± 0.55 d, while the duration of incision pain after operation was 5-12 h, with an average of 7.83 ± 2.48 h, which was significantly lower than that in the laparotomy group 13.07 ± 3.04 d and 29.37 ± 9.54 h, respectively ($P<0.001$). LDLT surgery was successful in all recipients. In the laparoscopic group, there was one case that died from hepatic artery embolization 60 d postoperatively and another case suffered from bile leakage at the liver graft section (cured). In the laparotomy group, there was one death due to postoperative hepatic artery embolization at 63 d and another two cases suffered from bile leakage at the liver graft section (cured). Conclusion: The laparoscopic technique for donor liver hepatectomy in pediatric living donor liver transplantation has strong potential to be widely applied as this surgery can reduce the length of postoperative hospitalization as well as the duration of incision pain.

Keywords: Pediatric, living donor liver transplantation, laparoscopic, hepatectomy

Introduction

In the field of surgery, laparoscopic technology was first used in gynecological examinations. Now with the development of science and technology, the laparoscope has been applied in various surgical fields [1, 2]. However, because of the potential risk of hemorrhage during liver surgery, the application of laparoscopic technology in liver surgery is relatively low [3]. According to four cases of laparoscopic hepatectomy of the donor liver in the living donor liver transplantation (LDLT) reported by Soubrane [4], Rotellar [5] and Brustia *et al.* [6], compared to the traditional abdominal hemihepatectomy of the donor liver in LDLT, laparoscopic hemihepatectomy of the donor liver has less trauma, quicker recovery, less bleeding, shorter hospitalization time, less postoperative pain and smaller scar. However, as laparoscopic living donor liver (LLDL) hepatectomy requires a surgeon to proficiently master the procedures of both laparoscopic technology and LDLT, there are few liver transplantation centers that can provide laparoscopic donor liver hemihepatectomy during LDLT in China. At the Organ Research Institute of Hospital of the Armed Police Corps of China, we have successfully performed six cases of laparoscopic left extrahepatic lobectomy of the donor liver in pediatric LDLT from January 2016 to December 2016. In this study, we compared outcomes between these cases and 11 cases of abdominal donor liver hepatectomy. Then the key points of laparoscopic left extrahepatic lobectomy of the donor liver in pediatric LDLT as well as its application prospects are summarized.

Table 1. Preoperative clinical data of donors undergoing laparoscopic or abdominal LDLT ($\overline{x}$ ± S)

	Laparoscope (n=6)	Laparotomy (n=11)	t	P
Age (month)	32.17 otomy	29.54 otomy	0.666	0.515
Hight (cm)	162.67 ± 62.6	164.27 ± 64.2	-0.375	0.713
Weight (kg)	58.335 tomy	63.545 tomy	-1.203	0.248
Liver weight of Donor (g)	228.33 eightc	279.82 ± 49.97	-2.131*	0.035

Note: *difference between laparoscopic group and laparotomy group is statistically significant.

Materials and methods

General data

We performed retrospective analysis of the clinical data of six cases of adult donor recipient total laparoscopic left extrahepatic lobectomy liver transplantation for recipient patients from January 2016 to December 2016 in the Organ Transplantation Institute, the General Hospital of Chinese Armed Police Force. Meanwhile, we selected 11 surgical cases who received abdominal left lateral hepatectomy in LDLT with adult donor and pediatric recipient between January 2014 and December 2016 as the control group, and collected their clinical data. The clinical data of the two groups of donor-recipient pairs are shown in **Table 1**. In addition, this study was approved by the Ethics Commission of the General Hospital of Chinese Armed Police Force, while all the donors and the guardians of the recipients provided signed informed consent.

Donor selection and evaluation

The examination items for donor selection and evaluation in laparoscopic and abdominal LDLT were basically consistent: whole blood cell analysis, blood biochemistry and infectious diseases indexes were analyzed before surgery. Chest X-ray, electrocardiogram, abdominal ultrasound and hepatic CT were also performed to assessed the anatomy of the donor liver and the blood vessels (the hepatic arterial branches, the portal vein branches and the hepatic vein branches) in order to evaluate any variation. Then 3D software was used to reconstruct the three-dimensional duct structure of the donor liver and to understand the anatomical relationships among the structures. Graft/Recipient's Body Weight Ratio (GRWR) was calculated for two groups of donor-recipient and computer simulation was used to visualize the section of hepatectomy. Finally, Magnetic Resonance Cholangiopancreatography (MRCP) was used to understand the donor biliary tract condition to evaluate if there was any variation.

Laparoscopic left extrahepatic lobectomy of the donor liver

The donor was operated on in a supine position with the waist padded high, and the head 30° higher than the feet while both lower extremities were spread bilaterally to make a 30° angle. Then a 2 cm-arc incision was made below the umbilicus. After successful pneumoperitoneum, the intra-abdominal pressure upper limit was set at 13 mmHg and the laparoscopic lens was inserted through a 10 mm trocar to examine the abdominal cavity. The endoscopic implantations were made of 10 mm trocar through a 1.5 cm incision at the following positions: 2 cm below the xiphoid, 2 cm below the costal margin at midclavicular line and 2 cm below the costal margin at right anterior axillary line, and an endoscopic implantation of 12 mm trocar was made through a 1.5 cm incision 2 cm below the costal margin at left anterior axillary line (**Figure 1**).

An ultrasound knife was used to disconnect the ligamentum teres hepatis, falciform ligament and left coronary ligament. Then the left deltoid ligament and the left border of left hepatic veins were isolated and the ligamentum hepatogastricum was opened. The front of caudate lobe was isolated and during the isolation, we carefully identified whether there was accessory left hepatic artery in the ligamentum hepatogastricum, if so, it was marked after complete isolation. Dissection of the first porta hepatis from left to right and isolation of the left hepatic artery was performed. If the middle hepatic artery was found during the procedure, it was isolated and marked it.

The left branch of portal vein was dissected and isolated to the crotch of the left and right branches with the assistance of ultrasonogra-

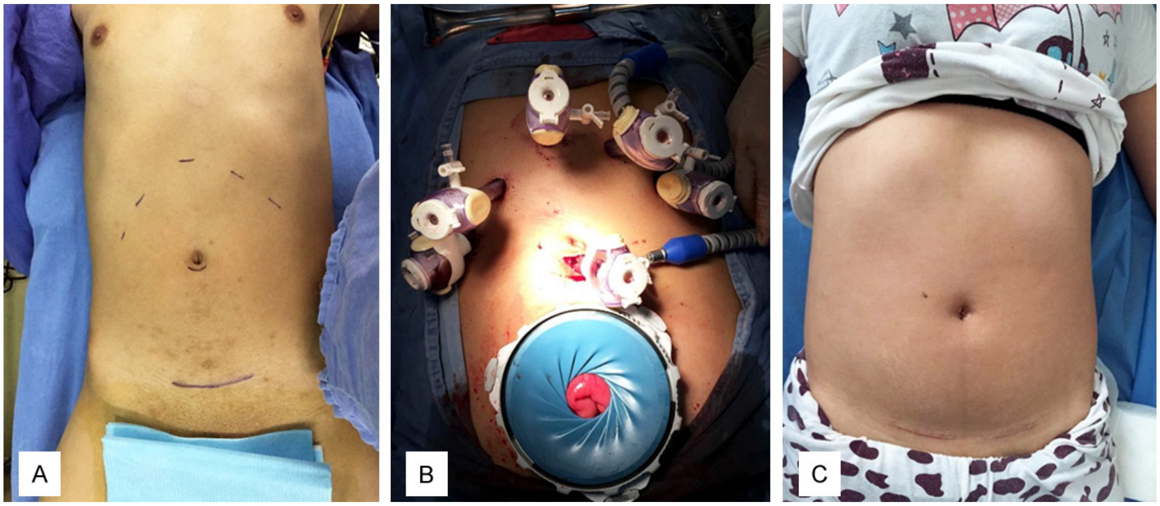

Figure 1. Locations of puncture outfits for laparoscopic left extrahepatic lobectomy of the donor liver. A. Incision sites at the trocars and above pubic symphysis marked before surgery; B. Positions of trocar insertion during the operation and the condition of the LapDisc after insertion through the incision above pubic symphysis; C. Abdominal incision scars 8-months postoperatively.

phy during the operation. Then the distance of middle hepatic artery to the right border of falciform ligament was carefully identified. The Glisson system of the left liver was isolated and clip the left hepatic duct with a metal clip. Finally radiography was performed by indwelling a Fleischl catheter at the fundus of gallbladder, and we made sure the images of both left and right hepatic ducts were well shown in order to determine the exact location of the dissected left hepatic duct.

Monopolar electric hooks, CUSA (Cicel, Germany. Host machine model: FS-1000-RF; Type of the cutter header handle: D218), associated ultrasound knife (Johnson & Johnson, USA. Host machine model: GENERATOR 300; Cutter head type: HARMONIC, ACE36E), ligasure (Covidien, USA. Host machine energy platform: ForceTriad; Laparoscopic cutter head: Razoredge 1737), Hem-o-lock (WECK, USA) and titanium clips (Johnson & Johnson, USA. Type: EL5ML) were used to cut along the mesial plane on the liver marked by the projection of the right border of falciform ligament and the middle hepatic vein, and dissect the hepatic tissues until the anterior caudate lobe. If ducts were encountered, we treated them in different ways according to their thickness. Specifically, wecut directly with ultrasound knife for those less than 1 mm in diameter whereas for those with a diameter between 1 mm and 5 mm, we clipped them off with a titanium clip and then cut them, finally those with the diameter greater than 5 mm were ligated and snipped with different models of Hem-o-lock one by one. Lastly, we separated the left main portal vein and left hepatic vein, disconnected the liver tissues from hepatic vein to the anterior caudate lobe of hilus hepatis plate with CUSA, and cut the small vessels as well as connective tissues with the ultrasound knife for closure.

A biclamp was used for effective hemostasis until the left lateral liver was completely separated, and in the meantime, the silicone catheter was used as a pulling band to assist in the identification of important structures as well as the complete amputation of liver parenchyma. We performed radiography again to confirm the biliary tract incision line, and ultrasonography to identify the position of right hepatic artery. A transverse skin incision of 7 cm was made 2 cm above the pubic symphysis, and then we hierarchically cut into the abdominal cavity along the midline to insert the LapDisc and imbed the specimen pocket. After making the decision to do complete disconnection of the left lateral liver and whole body heparinization has made by the anesthetist, we clipped off the left hepatic duct with Hem-o-lock and made a sharp incision. Finally we clipped off the left hepatic artery with Hem-o-lock and make a sharp incision. The Endo GIA ligasure (tri-stapler) from Covidien (USA) was used to disconnect the left portal vein and left hepatic vein,

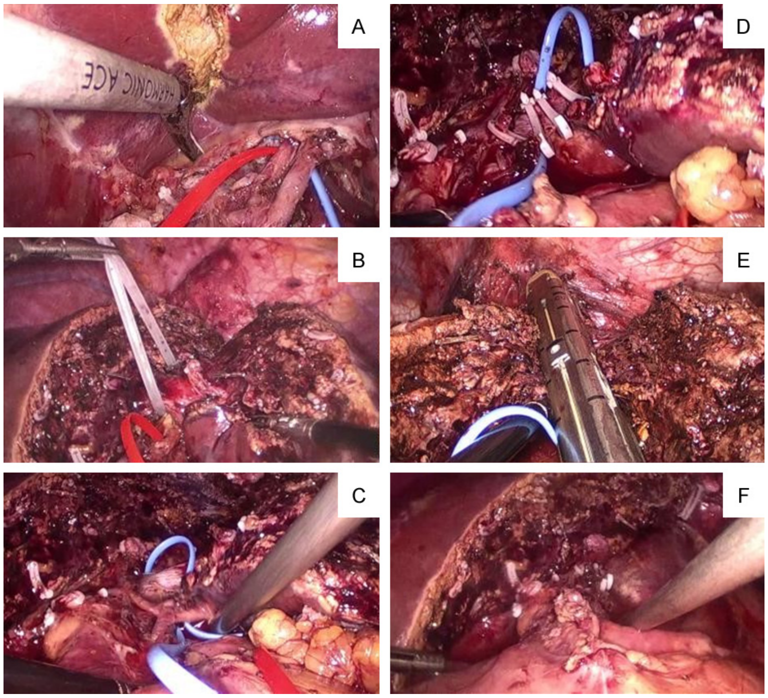

Figure 2. Laparoscopic images oflaparoscopic left extrahepatic lobectomy of donor liver. A. Liver parenchyma at 5mm depth from the split surface cut by an ultrasound knife after the complete dissection of the first porta hepatis; B. A silicone catheter was used as a pulling band to assist in the separation of important structures; C. The left hepatic artery and the main trunk of left portal vein after disconnection of the left hepatic duct; D. Hem-o-lock was used to clip off the main trunk of left portal vein in order to obstruct the main portal vein long enough for the graft procedure; E. ENDO GIA ligasure of the left hepatic vein; F. Lateral hepatic section of the donor liver after completion of hepatectomy.

Table 2. Preoperative clinical data for recipients of laparoscopic or abdominal LDLT

	Laparoscope (n=6)	Laparotomy (n=11)	Z/t	P
Age (month)	9.50 (7-14)	24.0 (6-156)	-1.262	0.207
Weight (kg)	8.33 ± 1.40	14.98 ± 8.87	-1.796	0.093
MELD (score)	13.50 ± 4.55	11.55 ± 6.01	0.692	0.449
Chind (score)	8.33 ± 1.63	6.64 ± 1.91	1.834	0.087
GRWR (%)	2.78 ± 0.38	2.44 ± 1.22	0.520	0.340
PELD	16.02 ± 8.17	13.89 ± 11.23	0.406	0.691

then the left lateral liver could be completely resected and removed through the incision above pubic symphysis. Another group of doctors should immediately perfuse the donor liver with 0°C HTK solution before trimming and weighing it (**Figure 2**).

Research methods

The clinical data was collected from six adult donors, children recipients, all receiving LLDL transplantation recipients as well as 11 adult donors, children recipients, left lateral liver living donors transplantation recipients. Preoperative clinical data (age, sex, height, weight, relationship to recipient, donor liver weight), preoperative clinical data (age, sex, weight, MELD score, Chind score, GRWR, PELD), primary pathogenesis of recipient, the perioperative index of donor liver extraction (operation time, intraoperative bleeding volume, hospitalization time, hot ischemia time, incision pain duration, complications), clinical outcome of recipient and other data were reviewed. The data are described by ($\overline{x}$ ± s) or median (M), and the numerical data are described as n (%).

The normal distribution data between the two groups were compared, and two independent sample t test were used for statistical testing. Comparison of non-normal distribution data between two groups was carried out by Wilcoxon rank sum test. Significant difference was considered to be P<0.05.

Results

Donor baseline data

Six cases of laparoscopic pediatric living donor liver transplantation donor liver incision in 3 male patients (all 3 cases were female, recipient's father) (both recipient's mother), the average liver weight (228.33 ± 27.87) g; and 11 cases of laparotomy group included six cases of male donor (recipient's father), five female donor cases (recipient's mother) with an average liver weight of 279.82 ± 49.97 g. The weight of the donor liver in laparotomy group was significantly higher than that in laparoscopy group, and the difference was statistically significant (t=2.313, P=0.035). In addition, the age, height and weight of the two

Table 3. Comparison of perioperative indexes among donor liver resection operations

	Laparoscope (n=6)	Laparotomy (n=11)	t	P
Operation time (min)	471.17 ± 106.56	327.45 ± 181.37	1.766	0.098
Intraoperative blood loss (ml)	173.34 ± 29.61	209.09 ± 58.39	-1.391	0.184
Time of hospitalization (d)	3.50 ± 0.55	13.07 ± 3.04	-7.705*	<0.001
Warm ischemia time (min)	5.17 ± 0.75	4.18 ± 1.17	1.852	0.084
Incisional pain time (h)	7.83 siona	29.37 ± 9.54	-5.355*	<0.001

Note: *Difference between laparoscopic group and laparotomy group is statistically significant.

groups were in the normal population, and there were no exceptional cases. Data is shown in **Table 1**.

Baseline data of the recipients

The youngest recipient was 7 months and the oldest was 14 months among the six cases of laparoscopic liver donor liver transplantation, including five males and one female. There were four cases of primary focus are recurrent cholangitis after congenital biliary atresia and two cases of decompensated cirrhosis after congenital biliary atresia. In laparotomy group, there were four males and seven females among the 11 donors. There were three cases of primary lesions that were recurrent cholangitis after congenital biliary atresia, two cases of congenital biliary atresia, three cases of spontaneous biliary cirrhosis, one case of glycogen accumulation disease, one case of hepatolenticular degeneration, and one case of Niemann Peake's disease. There were no significant difference in the age, weight, preoperative MELD score, Chind score, GRWR and PELD between the two groups. See **Table 2** for further details.

Comparison of perioperative indexes in donor liver resection operations

There were no complications in the laparoscopic group and the laparotomy group, and the safety of the laparoscopic donor liver removal was guaranteed. Laparoscopic postoperative hospitalization time was 3-4 days, (average length of hospitalization 3.50 ± 0.55 d), was less than the laparotomy group 13.07 ± 3.04 d, which was a significant difference (P<0.001). The duration of incision pain in laparoscopy group was 5-12 h, (average 7.83 ± 2.48 h), is lower than that in the laparotomy group (29.37 ± 9.54 h), which has a significant difference (P<0.001). Next, laparoscopic operation time was 330-647 min, (average 471.17 ± 106.56 min) was higher than the laparotomy group average operation time 327.45 ± 181.37 min. The laparoscopic group of intraoperative blood loss was 135-210 ml, (average 173.34 ± 29.61 ml) this was less than the average amount of bleeding in laparotomy group at 209.09 ± 58.39 ml and the laparoscopic group mean warm ischemia average time was 5.17 ± 0.75 min and laparotomy group was 4.18 ± 1.17 min. The difference between the above three indexes were not statistically significant. For details, see **Table 3**.

Surgical outcomes

All the 17 recipients received standard transplantations under the technical principles of adequate separation and reservation of the blood vessel and biliary tract for operation anastomosis, and all the operations were successful without any case of primary graft dysfunction. In the laparoscopic group, there was one case of hepatic artery embolism (the recipient died 60 d after the operation) and one case of bile leakage at the liver graft section (cured after adequate drainage and wound dressing) while there was no graft vascular complications. In the laparotomy group, there was one case of hepatic artery embolism (the recipient died 63 d after the operation) and two cases of bile leakage at the liver graft section (cured after adequate drainage and wound dressing) while there was no graft vascular complications.

Discussion

With the constant development of medical science and technology, laparoscopic technology has been continuously improved, and has gradually been applied in the field of LDLT. In 2002, the first laparoscopic left lateral hepatectomy of a donor liver in pediatric LDLT was performed by the Cherqui *et al.* [7]. Four years later, laparoscopic right lateral hepatectomy in LDLT was reported for the first time [8]. In 2012, Giulianotti *et al.* [9] conducted the first robot-assisted donor liver resection in the US. However, because laparoscopic left lateral hepatectomy of the donor liver in LDLT requires the surgeon to master both laparoscopic technology and LDLT. Even with 15 years of development of this technology, there are still few liver transplantation centers that can perform this operation in China, with most centers conducting less than 10 cases per year. Noteably, the Organ Research Institute of Hospital of the Armed Police Corps of China completed six cases of laparoscopic left lateral hepatectomy of the donor liver in pediatric LDLT in 2016.

Due to the high probability of single main portal vein, biliary tract as well as hepatic vein trunk in the hepatic left lateral lobe, and anatomical advantage of relatively small size as well as light weight, the hepatic left lateral lobe has less influence on the donor and is the most preferred organ for pediatric LDLT [10, 11]. In this study, we found that laparoscopic donor liver hepatectomy significantly reduced the time of postoperative hospitalization and incision pain without obviously changing the warm ischemia time or postoperative complication rate for the donor. Furthermore, we conclude that when performing laparoscopic donor liver hepatectomy, the liver incision plane should preferably be on the right of falciform ligament (the sagittal part of portal vein) and away from the flowing plane of middle hepatic vein in order to ensure the integrity of the main artery in the hepatic left lateral lobe. With the assistance of preoperative three-dimensional reconstruction of the blood vessels in the liver, the liver incision plane can be simulated by the computer and large vessels that might be encountered and need to be dealt with can be predicted.

During the laparoscopic donor liver hepatectomy, the surgeon should first make a small arc incision under the umbilicus and perform pneumoperitoneum, and then insert the trocar and laparoscope. The locations of other trocars on the abdominal wall should be decided according to the anatomy of the abdomen, rather than inflexibly locating the trocars by the theoretical positions painted on the abdominal wall before surgery. Additionally, the trocars should be inserted at an appropriate angle, and preferably the general types of 5 mm or 10 mm caliber trocars should be used in order to operate neatly by changing between different instruments during the surgery. Finally, the 300 lens setting on laproscope should be used to insure a wide vision field.

When dissecting the first hepatic hilum, we recommend using an ultrasound knife rather than the right-angle dissecting forceps, and then choose different disconnecting methods according to the tissue type. Also, avoid important structures during the dissection in order to avoid thermal collateral damage. When disconnecting the hepatic parenchymal plane, the utilization rate of the trocar on the right side of abdominal wall may be low for a right-handed surgeon due to the limitations the approach angle. In our experience, if the surgeon practices the operation with the left hand it is very beneficial in improving the utilization rate of the trocar on the right abdominal wall. For the laparotomy group, a pulling band can be used to assist the complete dissection of important structures (the left portal vein, the left hepatic duct and the left hepatic vein) in order to speed up the operation and effectively avoid damage to important structures. We successfully used pulling band technology in the laparoscopic group as well, which also sped up the operation. In this study, one of the six cases of laparoscopic donor liver resection were transferred to abdominal operation. In addition, according to the opinions of Samstein *et al.* [11], we preferentially chose prolate donor livers before the laparoscopic left extrahepatic lobectomy. In some cases, in order to provide longer left portal vein trunk to the recipients, the surgeon can clip off the left portal vein trunk of the donor with a large Hem-o-lock before disconnecting the graft while clipping off the distal side with a large titanium clip.

In terms of operation time, the laparoscopic group was longer than the laparotomy group, which can be explained with two reasons: learning curve effects and the operation procedure itself. Since the operational angle of laparoscopic liver dissection depends on the position of the trocars on abdominal wall, some angles are out of reach; while in the laparotomy group the operational angles are almost unrestricted. This can result in a significantly longer operation time in the laparoscopic group than in the laparotomy group. Notably, the operation time of the laparoscopic group in this study is basically close to that of other international transplantation centers [11-15]. According to the incision pain grading Numerical Rating Scale (NRS), patients with a score of 5 points or less could tolerate the pain without treatment with analgesics, while patients with a score over 5 points need oral administration of weak acting analgesic drugs [15]. Therefore, we compared the duration of postoperative incision pain that was scored over 5 points between the two groups, and the results showed that the time of incision pain in donors of the laparoscopic group was significantly shorter than that of the laparotomy group (P<0.001). We reasoned that this difference could be directly related to more severe abdominal wall trauma in the laparotomy group compared with the laparoscopic group. In addition, there was no postoperative death or postoperative complications in the six cases of laparoscopic hepatectomy donors in this study, which was far below the postoperative death rate of 0.16% and postoperative complication rate of 20% of the donors announced by 74 living liver transplantation centers in Europe [16]. This finding indirectly suggests that the laparoscopic donor liver hepatectomy in LDLT performed by our center has certain reference value.

Conclusion

Taken together our results show that the laparoscopic left extrahepatic lobectomy of a donor liver in LDLT benefits the donors with a faster recovery, shorter hospitalization time, less postoperative incision pain and smaller incision scarring without increased risk of surgical complications. This procedure therefore has the potentially to be widely applied in the clinic. However, studies with larger sample sizes are still required to verify whether laparoscopic left extrahepatic lobectomy of the donor liver is better than the traditional abdominal donor liver hepatectomy or laparoscope-assisted abdominal donor liver hepatectomy in LDLT.

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Disclosure of conflict of interest

None.

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