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ORIGINAL ARTICLE

Comparison of Laparoscopy-Assisted and Open Donor Right Hepatectomy: a Prospective Case-Matched Study from China

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Abstract
Background Laparoscopy-assisted hepatectomy is a new minimally invasive approach for graft harvesting in living donors. Only a few liver transplant centers have introduced this surgical procedure.
Methods A prospective case-matched study was conducted on 25 consecutive donors who underwent laparoscopy-assisted donor right hepatectomy (LADRH) between July 2011 and March 2013 at our transplant center. These donors were matched 1:1 according to age, gender, and body mass index with 25 donors who underwent open donor right hepatectomy (ODRH).
Results LADRH was successfully performed in all 25 of the donors. Donor complications, estimated blood loss, and operative time were similar between the groups. Hospital stay and periods of analgesic use were significantly shorter in the LADRH group [7.0±1.4 (LADRH) vs 8.7±2.4 (ODRH), $p=0.003$, and 2.4±1.0 (LADRH) vs 3.2±1.0 (ODRH), $p=0.011$, respectively). The total in-hospital cost is higher with LADRH, primarily due to the additional material costs for LADRH. Finally, there were no differences in graft size, graft survival, or recipient complications between the two groups.
Conclusion The results of this study show that LADRH is a feasible and safe procedure compared with ODRH. Although higher material costs for laparoscopic assisted procedures are inevitable, LADRH may have an advantage over ODRH by causing less pain and facilitating earlier recovery. Efforts can be made to improve the technical success of LADRH for some overweight donors.

Keywords Living liver donors · Laparoscopy-assisted donor hepatectomy · Minimal invasive surgery

Introduction

Living donor liver transplantation (LDLT) is an important option for patients with end-stage liver disease requiring liver transplantation.[1–3] Although conventional open donor right hepatectomy (ODRH) with a large right subcostal incision is well established and regarded to be the standard procedure for adult to adult LDLT, this procedure is limited by the surgical risks that are associated with a donor morbidity rate of 20–40 %.[4–7] In addition, wound-related complications, such as wound infection and wound pain, are observed in most cases with complications.[8, 9]

Recently, minimally invasive liver surgery has been widely applied.[10] Compared to conventional open surgery, laparoscopic surgery has the advantages of reduced postoperative pain, recovery time, and surgical morbidity.[11–14] Recent developments in laparoscopic surgery have demonstrated the safety and technical feasibility in live donor left or right hepatectomy. After the first laparoscopic living donor left lobectomy was successfully performed in 2002, [15] laparoscopic techniques and instruments for living donor hepatectomy have been developing quickly.[16–18] In 2006, Koffron et al.[16] and Kurosaki et al.[17] simultaneously successfully performed laparoscopic-assisted donor right hepatectomy (LADRH) using similar surgical methods. However, until now, only a few studies have reported outcomes comparing LADRH and ODRH, all of which were retrospective studies.[18–20]

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We conducted a prospective case-matched study that compared the outcomes of LADRHs with those of ODRHs at our transplant center.

Patients and Methods

Study Design

We prospectively designed a study to assess the potential benefits of LADRH at our transplant center. Two experienced transplantation surgeons, who were fully trained with ODRH and laparoscopic-assisted right hepatectomy for patients with liver tumors before this study was initiated, were involved in this study. All donors received patient-controlled intravenous analgesia in the form of sufentanil combined with tramadol and granisetron in the immediate postoperative period. All of the donor patients were discharged from the hospital with normal diet and activity when fully recovered. During the median follow-up time of 16 months (range, 5–27 months), any event that deviated from the normal course of recovery was recorded as a complication. Each donor who underwent LADRH was retrospectively matched one to one with donors who underwent ODRH before we introduced this hybrid technique in live donors. Matching criteria included age, gender, and body mass index (BMI).

Population

We have performed 304 living donor liver transplants at our transplant center since January 2001 with 25 successive LADRHs between July 2011 and March 2013. The selection criteria for donors for this laparoscopic surgery were volunteers with the ability and willingness to undergo this minimal invasive procedure. Informed consent was obtained from all 25 of the donor patients before their participation in the study. We compared donor and recipient allograft outcomes with 25 matched cases of ODRH from April 2009 to June 2011 to minimize any experience bias.

Outcome Measures

The assessment of perioperative parameters included the operative time, estimated blood loss, graft weight, postoperative serum levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT), and total bilirubin (TB) in donors and recipients, length of hospital stay, period of patient-controlled intravenous analgesia use, hospital costs, and postoperative complications. Continuous variables were reported as the mean±standard deviation and comparisons were made using Student's t tests. Categorical variables were compared using Fisher's exact test. All reported P values are two-sided and considered statistically significant at levels less than 0.05.

Surgical Technique

Our technique for LADRH is a hybrid approach that is similar to what Koffron et al.[16] have previously described, including a 5-cm subxiphoid midline incision created for hand assistance during right lobe manipulation, a 12-mm umbilical port for laparoscope, and a 12-mm right lateral subcostal port at the midclavicular line as a working port (Fig. 1). After the subxiphoid midline incision was created, the ligamentum teres were divided under direct vision and then a GelPort hand port device (ETHICON ENDO-SURGERY, Guaynabo, Puerto Rico, USA) was installed. Using a Harmonic™ scalpel (ETHICON ENDO-SURGERY, Guaynabo, Puerto Rico, USA) under laparoscopy, falciform, right triangular, hepatorenal, and coronary ligaments were divided with hand assistance until the whole hepatic bare area was mobilized (Fig. 2a). The right lobe was elevated to expose the length of the retrohepatic inferior vena cava (IVC). The short hepatic veins, inferior right hepatic veins (if existing), and the posterior vena cava ligament were divided using Him-o-lok clips (WECK, The Research Triangle Park, North Carolina, USA) and scissors until the right hepatic vein was isolated (Fig. 2b–d). The abdomen was then deflated, the hand port and all other laparoscopic devices were removed, and the middle incision was extended to 12 cm. Next, cholecystectomy, hilar dissection, and liver resection were completed under direct vision in the same manner as the standard open procedure. Any middle hepatic vein branches of over 5 mm in diameter were clipped and cut for reconstruction. ODRH was performed as we previously reported[21] using a large right subcostal incision for right hepatectomy (Fig. 3).

Fig. 1 Port placement for LADRH. Two ports and a GelPort hand port device are shown, and an assisted hand is put into the abdomen through the hand port device

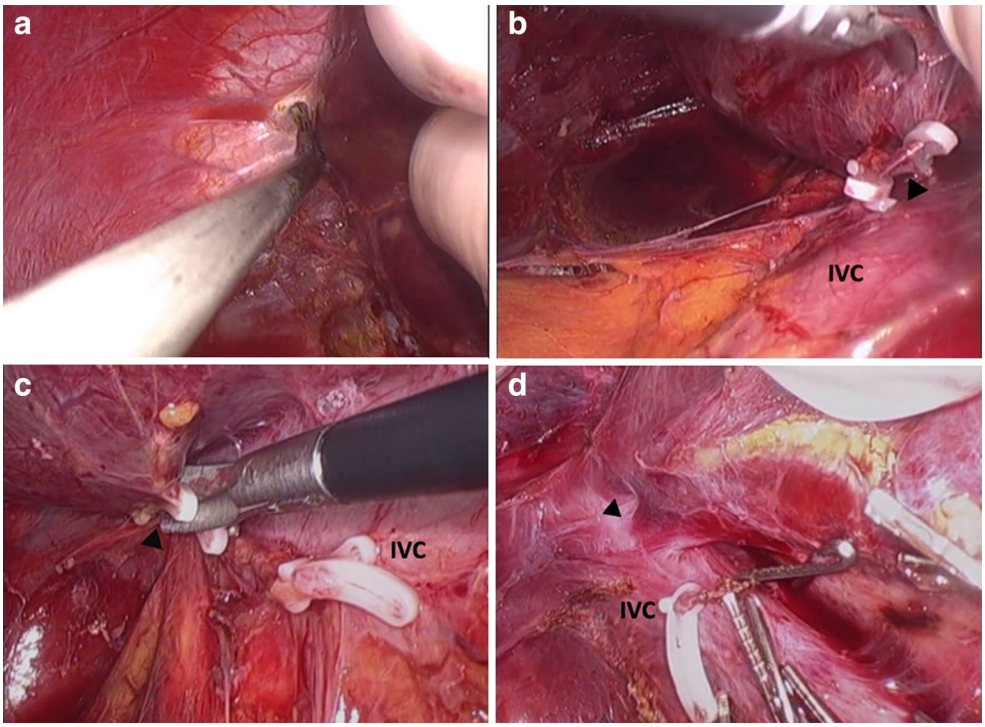

Fig. 2 Mobilization of the right liver. **a** The right triangular ligament of the liver is divided with hand assistance. **b** A short hepatic vein (*black up-pointing triangle*) is clipped and will be divided by a laparoscopic scissor. **c** The posterior vena cava ligament (*black up-pointing triangle*) is clipped and divided. **d** The right hepatic vein (*black up-pointing triangle*) was isolated

Results

Using the laparoscopic-assisted technique as described, all of 25 successive LADRHs were successfully performed at our transplant center and no cases were converted to standard open donation. Donor demographics for LADRH and ODRH including age, sex, BMI, and anatomic anomalies were similar. The mean operative time was slightly longer in the LADRH group (385.9±47.4) compared with that in the ODRH group (378.1±59.0, $p=0.611$). LADRH was associated with a lower estimated blood loss, although this difference was not statistically significant between groups (378.4±112.5 vs 422.6±139.3, $p=0.229$). None of the donors in either group required a banked blood transfusion during surgery. Additionally, the mean graft weight was comparable between groups. These data showed no selection bias based on the donor baseline characteristics between the groups. Recipient demographics were also comparable between the LADRH and ODRH groups. There were no significant differences in the mean age, sex, MELD score, or primary diseases between groups.

The incidence of donor complications had no statistically significant difference between the groups. According to the original Clavien scale,[9] three (12 %) grade I complications were observed in the LADRH group compared with six (24 %) in the ODRH group ($p=0.232$). Three cases of pleural effusion and pulmonary infection occurred in the two groups. Two cases of wound infection occurred only in the ODRH group. In addition, one ODRH donor had a minor bile leakage after the operation. This abnormality resolved under observation and drainage within 1 month and did not require a reoperation. One grade II complication was observed in each

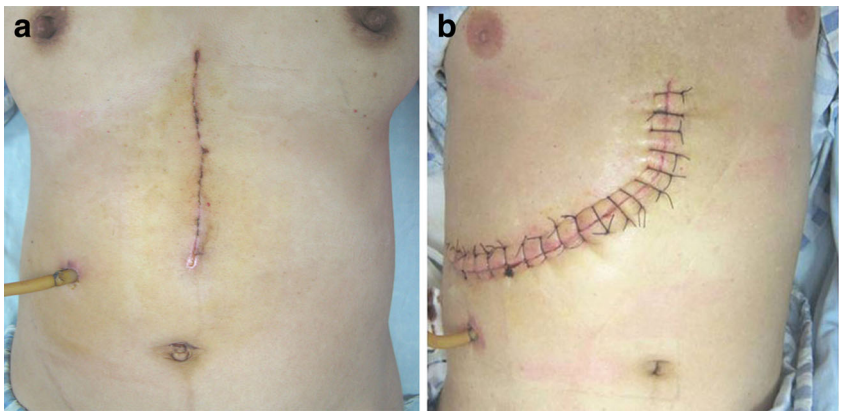

Fig. 3 Wounds from LADRH and ODRH. **a** A 12-cm upper middle incision (LADRH); **b** a 25-cm large subcostal incision (ODRH)

group. Both of these two grade II donors received reoperation, one for postoperative bleeding at the cut surface of the liver in the LADRH group and the other for intra-abdominal abscess in the ODRH group. None of the donors developed grade III (residual disability) or grade IV (retransplantation or death) complications in either group. No long-term complications occurred in either group during the follow-up period (LADRH mean, 16 months and ODRH mean, 34 months).

Compared with the ODRH group, donors in the LADRH group had a shorter hospital stay (7.0±1.4 vs 8.7±2.4, $p=0.003$) and a shorter period of analgesic use (2.4±1.0 vs 3.2±1.0, $p=0.011$). In contrast, the average total in-hospital cost was significantly higher for LADRH ($7,652.5±1,291.2) than ODRH ($6,540.8±1,113.0, $p=0.002$). After stratification, significantly higher operative supply cost was needed in the LADRH group ($3,311.7±617.5) compared to the ODRH group ($1,940.2±442.7, $p<0.001$) (Table 1).

All 50 of the right lobe liver grafts without inclusion of the middle hepatic vein were successfully transplanted in both groups. Recipient demographics were similar. Cold ischemic time, warm ischemic time, and graft versus recipient body weight ratio (GRWR)[22] were comparable between the two groups. There were also no significant differences in the peak serum levels of TB, ALT, and AST between the LADRH and ODRH groups. Moreover, there were also no significant differences in the incidence rate of recipient

Table 1 Comparison between LARDH and ODRH: donors' perioperative characteristics

Analyzed factors	LARDH ($n=25$)	ODRH ($n=25$)	p value
Preoperative variables			
Age (years)	37.2±8.7 (22–57)	37.4±10.5 (20–56)	0.953
Sex (male/female)	13/12	14/11	0.500
Body mass index	23.8±2.6	22.6±3.0	0.145
Intraoperative variables			
Operative time (min)	385.9±47.4	378.1±59.0	0.611
Estimated blood loss (ml)	378.4±112.5	422.6±139.3	0.229
Graft weight (g)	629.9±128.9	575.2±136.3	0.152
Postoperative variables			
Total bilirubin (μmol/L)			
POD 1	50.5±18.2	51.5±22.9	0.860
POD 7	21.2±8.1	18.6±5.9	0.214
Peak	52.4±21.6	53.8±25.7	0.840
ALT (IU/L)			
POD 1	242.0±97.0	250.0±94.0	0.771
POD 7	50.6±23.6	51.9±23.0	0.852
Peak	253.0±115.8	258.4±100.7	0.862
AST (IU/L)			
POD 1	179.8±85.2	181.0±76.9	0.957
POD 7	39.9±14.2	42.5±14.2	0.521
Peak	185.8±96.7	188.3±89.9	0.927
Length of hospital stay (days)	7.0±1.4	8.7±2.4	0.003
Period of analgesic use (days)	2.4±1.0	3.2±1.0	0.011
Total in-hospital cost (USD)	7,652.5±1,291.2	6,540.8±1,113.0	0.002
Operative supply cost	3,311.7±617.5	1,940.2±442.7	<0.001
Non-operative supply cost	4,340.8±1,135.3	4,600.6±913.5	0.377
Complications (Clavien classification)			
Grade I	3 (12 %)	6 (24 %)	0.232
Pleural effusion	1	2	0.500
Pulmonary infection	2	1	0.500
Wound infection	0	2	0.245
Biliary leakage	0	1	0.500
Grade II	1 (4 %)	1 (4 %)	0.755
Bleeding	1	0	0.500
Intra-abdominal abscesses	0	1	0.500

ALT alanine aminotransferase, *AST* aspartate aminotransferase, *INR* international normalized ratio, *POD* postoperative day

complications between groups. Only two deaths among recipients were observed in the ODRH group: one for recurrent hepatocellular carcinoma and the other for respiratory failure (Table 2).

Discussion

According to the development of minimal invasive liver surgery, LADRH has recently been successfully introduced in LDLT.[16, 17] There are two major steps in this hybrid technique described as follows. First, hand-assisted laparoscopic mobilization of the right hepatic lobe is performed. Second, hilar dissection and parenchymal transection are performed as an open procedure. Laparoscopic mobilization of the right hepatic lobe with hand assistance is the essential and difficult component of this operation. Although this hybrid technique has been successfully performed in more than 30 selected donors, as reported in the largest series of patients who underwent the procedure, two cases in the LADRH group were ultimately converted to the standard open approach in the interest of donor safety.[19] Unfortunately, the reason for the adaptation was not further discussed in that study. According to our early experience in laparoscopic-assisted right hepatectomy for patients with benign tumors, we found that in some cases overweight patients, the amount of fat tissue in the abdomen made the laparoscopic mobilization of the right liver lobe technically difficult because of an insufficient operative field. In those situations, only a 5-cm midline epigastric hand-port incision, a 12-mm umbilical port, and a 10-mm right lateral subcostal port appears not to be sufficient for performing the procedure. To improve the technical success of LADRH, we made some technical changes as follows. First, in some overweight donors (BMI >25 kg/m^2), an additional 12-mm right lateral subcostal port at the right midaxillary line was added for the operator to use a laparoscopic retractor to make a clear operative field. Second, in cases where exposure to the retrohepatic IVC after the right hepatic ligaments had been dissected was very difficult, the scheduled remaining laparoscopic procedure, including

Table 2 Comparison between LARDH and ODRH: recipients' perioperative characteristics

Analyzed factors	LARDH (n=25)	ODRH (n=25)	p value
Preoperative variables			
Age (years)	42.8±8.3	43.2±10.0	0.898
Sex (male/female)	20/5	18/7	0.371
MELD score	13.3±5.9	15.1±7.0	0.331
Primary diseases			
HBV-related liver cirrhosis (with HCC)	21 (13)	20 (12)	0.500
Fulminant hepatitis	3	3	0.666
Budd–Chiari syndrome	1	0	0.500
Alcoholic cirrhosis	0	1	0.500
Primary biliary cirrhosis	0	1	0.500
Intraoperative variables			
GRWR	0.99±0.20	0.99±0.14	0.357
Cold ischemic time	68.7±18.6	70.6±22.2	0.747
Warm ischemic time	37.3±10.1	40.5±11.4	0.305
Postoperative variables			
Total bilirubin: peak (μmol/L)	82.5±56.6	85.9±85.4	0.866
ALT: peak (IU/L)	404.2±469.5	467.5±451.1	0.629
AST: peak (IU/L)	329.7±380.3	365.3±331.5	0.726
INR: peak	1.80±0.46	1.62±1.02	0.431
Complications			
Biliary stricture	1	0	0.500
Biliary leakage	0	1	0.500
Hepatic artery thrombosis	1	0	0.500
Intra-abdominal bleeding	1	2	0.500
Intra-abdominal abscesses	1	0	0.500
Pleural effusion	0	1	0.500
Pulmonary infection	1	2	0.500
Mortality	0	2	0.500

ALT alanine aminotransferase, *AST* aspartate aminotransferase, *INR* international normalized ratio, *GRWR* graft versus recipient body weight ratio, *HCC* hepatocellular carcinoma, *MELD* Model for End-Stage Liver Disease, *POD* post-operative day

dissection of short hepatic veins and posterior vena cava ligament, was performed under direct vision through the upper middle incision. In the present study, using these technical changes in difficult cases, all of the 25 consecutive cases in the LADRH group were successfully performed with no cases requiring conversion to a standard open donation. Considering the majority of living donors are not obese, we strongly believe that this technique has the potential to be applied to every living liver donor.

The primary discrepant results in donors who underwent LADRH or ODRH are the size and site of the surgical incisions. Compared with the conventional standard open donation with a large right subcostal incision requiring a length of at least 25 cm, this hybrid approach for liver graft harvesting achieves a much smaller incision, approximately 12 cm, without cutting the subcostal nerve and muscle. Additionally, this method also retains the safety and familiarity of an open dissection and resection. This minimally invasive approach has several benefits, the results of our study showed that LADRH was associated with significantly less analgesic use and shorter hospital stays. However, this was at the cost of a significantly higher total in-hospital cost of LADRH. After further analysis, we found that this was the results of the additional material cost for LADRH. Excluding the operative supply costs, actually, the other hospital costs were similar between groups.

Our results indicate that this hybrid technique is feasible and safe. The average operative time was comparable between groups. This result is inconsistent with the prior reports showing significantly shorter average operative time with LADRH.[19, 20] Although the small incision of LADRH could reduce the time involved in opening and closing the abdomen, this seems to be balanced by the additional time required to mobilize the right lobe of the liver under laparoscopy according to our experience. Postoperative complications of donors were similar between groups, and no severe complications occurred in either group. Although not associated directly with this minimal invasive incision, one case of postoperative bleeding at the cut surface of the liver occurred and required an immediate reoperation, without extension of the incision to control the bleeding immediately. Two cases of wound infection occurred, both in the ODRH group. Although this difference was not significant between groups, we suppose this new small incision may present the potential benefit of reducing incision complications compared with the traditional large subcostal incision. However, to verify this, well-conducted large sample size studies on LADRH are needed. Finally, our data shows equitable graft and recipient outcomes between the groups. There were no statistically significant differences in the incidence of postoperative complications or measures of early graft function after transplantation between the recipient groups.

In conclusion, our study shows that LADRH is a feasible and safe procedure in comparison to ODRH. LADRH provides equitable grafts for the recipient with equal graft survival and complication rates. Although higher material costs for the laparoscopic assisted procedure are inevitable, LADRH may have the advantage over ODRH in allowing less pain and earlier recovery. Efforts can be made to overcome the technical difficulty of LADRH in some overweight donors.

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Conflict of Interest No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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