Original article

Comparison of open and laparoscopic live donor left lateral sectionectomy

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Background: The present study was undertaken to determine whether laparoscopic live donor left lateral sectionectomy (LLS) in paediatric liver transplantation is a feasible, safe and reproducible procedure, compared with open live donor left lateral sectionectomy (OLS).

Methods: A retrospective review was conducted of all consecutive live donor procedures for paediatric liver transplantation performed between May 2008 and October 2009. All live donor hepatectomies were carried out by a single surgeon.

Results: A total of 26 live donor procedures for paediatric liver transplantation were performed, of which 11 were LLS and 11 OLS; four left hepatectomies were excluded. The LLS group had a significantly shorter hospital stay (mean(s.d.) 6·9(0·3) *versus* 9·8(0·9) days; $P = 0·001$) and time to oral diet (2·1(0·3) *versus* 2·7(0·4) days; $P = 0·012$). Duration of operation, blood loss, warm ischaemia time and out-of-pocket medical costs were comparable between groups. There was no death in either donor group and only one complication, a wound seroma, in the OLS group.

Conclusion: LLS seemed to be a safe, feasible and reproducible procedure, and was associated with reduced hospital stay.

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Introduction

Owing to the shortage of deceased donor organs, live donor liver transplantation (LDLT) has become an established treatment for patients with acute and chronic liver disease. The first successful paediatric LDLT, of a left lateral section graft from a mother to her son, was performed in Brisbane, Australia in 1989[1]. Since then, this life-saving procedure has been applied to adult patients. Recent reports have suggested that the laparoscopic approach to left lateral resections for tumours should be the standard[2,3]. Laparoscopic live donor left lateral sectionectomy (LLS) was first described in 2002[4], indicating that this technique was feasible for paediatric liver transplantation. Subsequently, laparoscopic procurement of left lateral sections was shown to be safe and reproducible, resulting in grafts similar to those obtained by open surgery[5].

The authors of the present study have performed LLS in paediatric liver transplantation since May 2008. To determine whether LLS is a feasible, safe and reproducible procedure in paediatric liver transplantation, the outcomes of LLS were compared with those of open live donor left lateral sectionectomy (OLS).

Methods

Between February 1997 and October 2009, 1759 adult-to-adult LDLTs were performed at Asan Medical Centre; 141 paediatric LDLTs were carried out since December 1994, and 93 laparoscopic liver resections from July 2007 to October 2009. LLS was performed by surgeons with extensive experience in live donor hepatectomy and laparoscopic hepatectomy. Between May 2008 and October 2009, 34 paediatric liver transplantations were performed, including 26 LDLTs and eight deceased donor liver transplantations. All live donor hepatectomies in paediatric liver transplantation were performed consecutively by a single surgeon in this study. Four patients underwent left hepatectomy and were excluded. Thus, the study

population consisted of 22 donors undergoing left lateral sectionectomy, of whom 11 had LLS and 11 OLS.

This study focused on donor surgical procedures, results of donor and recipient operations, and medical costs with respect to the donor. Specifically, out-of-pocket medical costs related to the donors were compared, not total medical costs including insurance, in order to evaluate the actual personal costs.

Donor selection

Each donation was approved by the ethics committee of the local authority and by the Korean Network for Organ Sharing, which is affiliated with the Korean Ministry of Health. The legal age of consent for organ donation in Korea is 20 years, but can be lowered to 16 years when the recipient is the donor's parent, brother or sister. Adolescent donor candidates were interviewed carefully and repeatedly, and subjected to repeated psychological evaluations, to ensure that consent had not been coerced. In this study all donors were the recipient's father or mother except for one, who was the sister of the recipient.

Pretransplantation evaluation of donors included standard liver function tests, testing for hepatitis B and C and cytomegalovirus, Doppler ultrasonography, triphasic liver computed tomography (CT) with volumetry, percutaneous biopsy and indocyanine green retention test. The graft volume was calculated before surgery by CT and actual graft weight was measured by means of a dial scale at the back table. The sum of macrovesicular and microvesicular hepatic steatosis on pathological examination of the biopsy had to be less than 30 per cent[6,7]. Donors were given a thorough explanation of the advantages and disadvantages of open and laparoscopic donor hepatectomy, after which they decided on their preferred type of operation. For urgent paediatric LDLTs, open donor hepatectomies were preferred from the surgeon's viewpoint. Anatomical abnormalities, such as a left hepatic artery arising from the left gastric artery and a right posterior bile duct draining into the left hepatic duct (type D1)[8], were not obstacles to the performance of LLS.

Surgical procedure

Open donor surgery

The abdomen was explored using a J-shaped or midline skin incision and the left lateral section was drawn to the left of the round ligament after dissection of the left triangular ligament. In a separate procedure applied to the hilar vascular structure, the left hepatic artery and portal vein were exposed and isolated, with each vessel looped after dissection of the connective tissue. The hepatic parenchyma was divided along the right side of the falciform ligament using an ultrasonic aspirator (CUSA EXcel™; Valleylab, Boulder, Colorado, USA) and the pedicles to segment IV were divided. After transection of the parenchyma, intraoperative cholangiography was used to divide the left hepatic duct between two radio-opaque rubber bands, tagged transversely on the proposed dividing site of the left hepatic duct by holding sutures[7]. The left hepatic vein was divided using a vascular clamp and the stump was closed with 5/0 Prolene® (Ethicon, Johnson & Johnson, Somerville, New Jersey, USA) continuous suture. Finally, the left lateral liver graft was procured at the completion of surgery on the recipient. Follow-up CT was carried out routinely 5 days after surgery.

Laparoscopic donor surgery

The donor was placed supine in the 30° reversed Trendelenburg position, with the surgeon standing between the donor's legs. No Pringle manoeuvre was used during parenchymal division. Carbon dioxide pneumoperitoneum was maintained at 12 mmHg. One monitor each was placed on the middle and right side of the donor. Five trocars were usually inserted, with the middle trocar used as the primary working device (*Fig. 1*). The liver

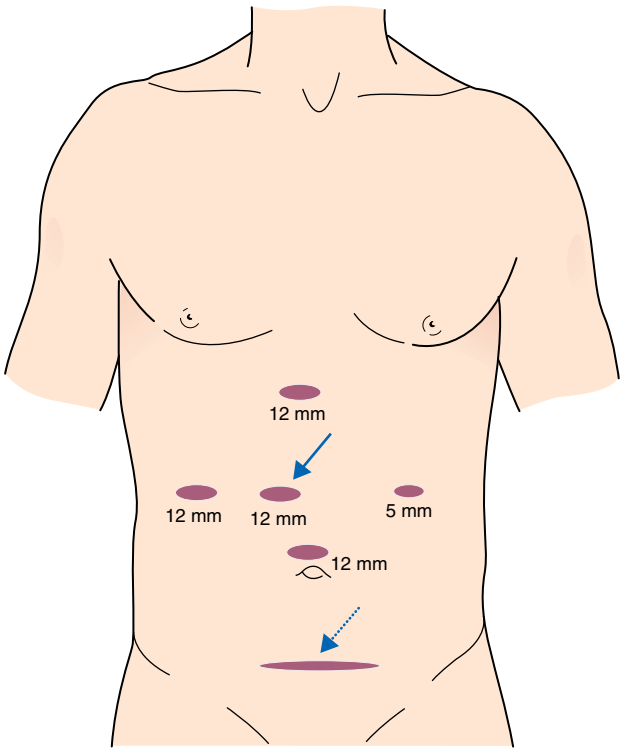

Fig. 1 Trocar position. The solid arrow indicates the main working port of the surgical aspirator, and the dotted arrow the graft retrieval site

was inspected with a 30° laparoscope and resected partially to obtain a frozen biopsy to confirm the degree of steatosis.

The laparoscopic surgical procedures are shown in *Fig. 2* and *Video S1* (supporting information). The left triangular and falciform ligament were divided with a Harmonic Scalpel™ (Ethicon Endosurgery, Cincinnati, Ohio, USA) to free the left lateral sector. The round ligament, used as a supporter, was divided after complete dissection of the left side of the hepatoduodenal ligament. The left hepatic artery and portal vein were identified and taped using an atraumatic grasper (Direct Drive® laparoscopic grasper; Applied Medical Resources, Rancho Santa Margarita, California, USA) and monopolar dissector. Some small branches going to the caudate lobe were clipped and divided to get sufficient length of the left hepatic artery and portal vein. The deep hepatic parenchyma was divided along the right side of the round and falciform ligament, using a laparoscopic ultrasonic aspirator (CUSA EXcel™). The liver capsule and superficial parenchyma were dissected using a Harmonic Scalpel™. The glissonian pedicles of segment IV were ligated using a knot pusher (5 mm knot guide; MGB Endoscopy Corporation, Seoul, Korea), or were clipped and divided. When the liver division reached the left hepatic vein, the left lateral sector was surrounded by a cotton tape that was passed under the left hepatic vein, portal vein and hepatic artery for a liver 'hanging-over' manoeuvre. The left bile duct was exposed after complete division of the remnant hepatic parenchyma, and was cut just above a Hem-o-lok® clip (Weck Closure System, Research Triangle Park, North Carolina, USA) that was clipped on to the proposed target level of the left hepatic duct. When there was a type D1 biliary anomaly (the right posterior duct draining into the left bile duct), the left bile duct was cut following intraoperative cholangiography by the C-arm, in which contrast was infused via the cystic duct through a cobra tube (Torcon NB® Advantage catheter; Cook Medical, Bloomington, Indiana, USA) after Hem-o-lok® clipping of the targeted level.

After infusion of 5000 units of heparin, the proximal end of the left hepatic artery was clipped and divided using a Hem-o-lok® clip, and the left portal vein was also clipped and divided. A unilateral linear stapler (30 mm Endo TA; US Surgical, Norwalk, Connecticut, USA) was used to cut the left hepatic vein. The graft was placed in an endobag inserted through a 12-mm trocar and retrieved through a 10-cm suprapubic incision site.

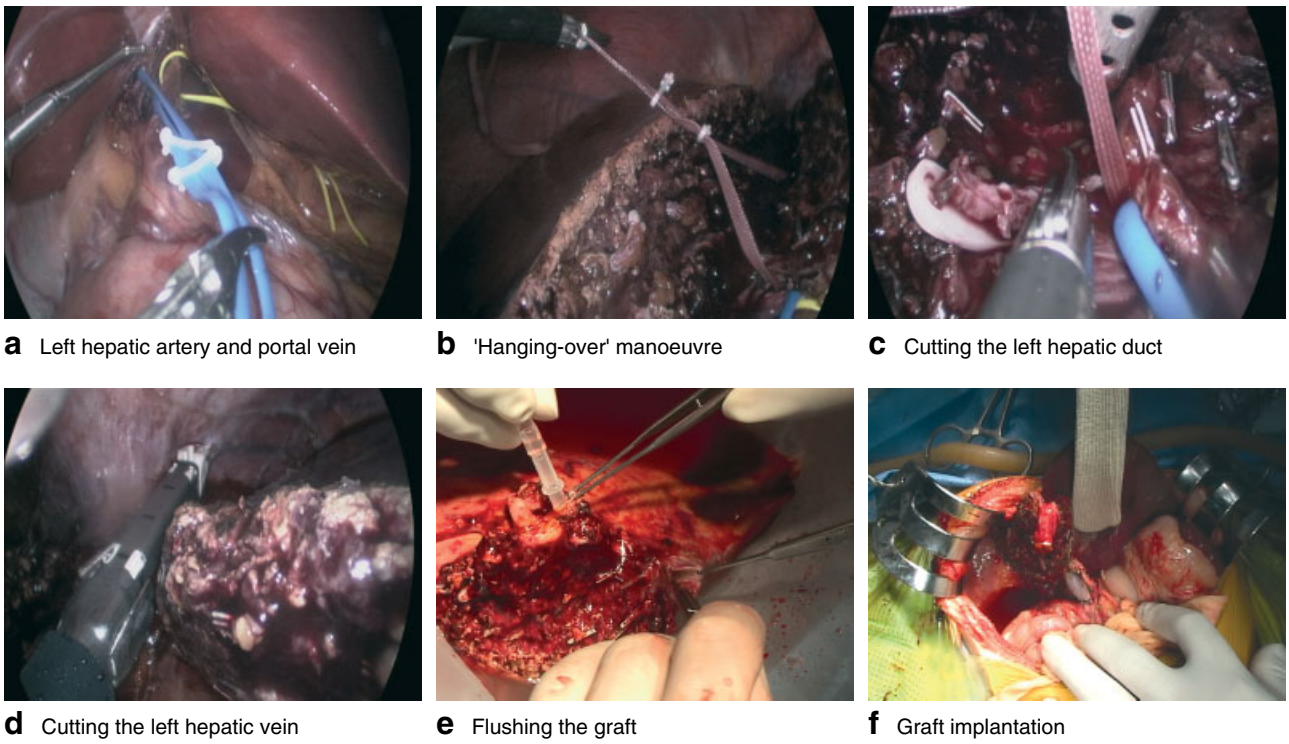

Fig. 2 Operative procedures in laparoscopic live donor left lateral sectionectomy: **a** left hepatic artery (yellow tape) and portal vein (blue tape); **b** 'hanging-over' manoeuvre; **c** cutting the left hepatic duct just above the Hem-o-lok® clip; **d** cutting the left hepatic vein using a linear stapler; **e** flushing the graft on the back table; **f** graft implantation

The graft was flushed on the back table with 1 litre of histidine–tryptophan–ketoglutarate (HTK) solution (Odyssey Pharmaceuticals, East Hanover, New Jersey, USA) at 4°C through the left portal vein. The suprapubic wound was then closed and carbon dioxide gas was reinsufflated to check haemostasis and biliostasis. Two closed suction drains were inserted to prevent fluid collection. Follow-up CT was carried out routinely 5 days after operation.

Statistical analysis

Continuous data were presented as mean(s.d.) unless indicated otherwise. Pre- and postoperative laboratory data of the donors, and postoperative outcomes of recipients, were compared between LLS and OLS groups using the Mann–Whitney *U* test for continuous variables and Fisher's exact test for categorical variables. $P < 0{\cdot}050$ was considered statistically significant. SPSS® version 12·0 (SPSS, Chicago, Illinois, USA) was used for all statistical analyses.

Results

Preoperative donor characteristics

Mean age was lower in the LLS group than in the OLS group (29·6(5·7) *versus* 35·2(3·8) years; $P = 0{\cdot}011$). The LLS donor group showed a female preponderance. There were no statistical differences in laboratory data between the LLS and OLS donor groups (*Table 1*).

Postoperative donor characteristics

There were no significant differences between LLS and OLS groups in procured graft volume, haemoglobin level on the day after operation or minimum prothrombin time (*Table 2*). However, the postoperative peak concentration of aspartate aminotransferase (AST) was significantly lower in the LLS group. The peak alanine aminotransferase concentration tended to be lower in the LLS group, whereas peak total bilirubin concentrations were similar. The LLS group had a significantly shorter hospital stay and time to oral diet intake.

Intraoperative characteristics

The mean duration of donor operation was 330(68) min in the LLS and 306(29) min in the OLS group ($P = 0{\cdot}272$), and mean blood loss was 396(72) and 464(78) ml respectively ($P = 0{\cdot}063$). The warm ischaemia time, or the time to retrieve a graft from the abdomen, was 6(2) min in the LLS group and 5(1) min in the OLS group ($P = 0{\cdot}074$).

Postoperative complications

There was no death in either group and only one complication, wound seroma, which was managed without surgical intervention in the OLS group.

Outcomes in paediatric recipients

There were no significant differences in preoperative data between the two groups, except that the paediatric end-stage liver disease (PELD) score was higher in the OLS group. Postoperative laboratory values were similar (*Table 3*). Two postoperative complications were observed in the LLS group: portal vein stenosis at 4 months in one patient, and biliary anastomotic stenosis at 10 months, managed by percutaneous transhepatic biliary drainage, in another. Two recipients in the OLS group developed

Table 1 Preoperative donor characteristics

	LLS ($n = 11$)	OLS ($n = 11$)	P†
Age (years)	29·6(5·7)	35·2(3·8)	0·011
Sex ratio (M : F)	1 : 10	6 : 5	0·065‡
Graft volume (ml)*	232·4(30·8)	245·3(46·7)	0·351
Haemoglobin (g/dl)	13·3(1·1)	13·5(1·6)	0·732
Prothrombin time (%)	94·5(29·1)	99·9(10·6)	0·615
Total bilirubin (μmol/l)	15·3(11·9)	13·6(3·4)	0·802
AST (units/l)	18·1(3·8)	19·9(6·6)	0·531
ALT (units/l)	16·7(9·1)	18·5(10·8)	0·382

Values are mean(s.d.) unless indicated otherwise. *Calculated by computed tomography. LLS, laparoscopic live donor left lateral sectionectomy; OLS, open live donor left lateral sectionectomy; AST, aspartate aminotransferase; ALT, alanine aminotransferase. †Mann–Whitney *U* test, except ‡Fisher's exact test.

Table 2 Postoperative donor characteristics

	LLS ($n = 11$)	OLS ($n = 11$)	P‡
Graft volume (ml)*	230·4(42·7)	258·6(47·5)	0·142
Haemoglobin (g/dl)†	11·1(1·6)	12·1(1·8)	0·176
Minimum prothrombin time (%)	71·6(13·8)	68·9(7·7)	0·835
Peak values			
AST (units/l)	191·0(124·2)	459·4(444·9)	0·029
ALT (units/l)	269·6(256·7)	492·0(367·2)	0·067
Total bilirubin (μmol/l)	27·2(11·9)	25·6(8·5)	0·912
Hospital stay (days)	6·9(0·3)	9·8(0·9)	0·001
Time to dietary intake (days)	2·1(0·3)	2·7(0·4)	0·012

Values are mean(s.d.). *Actual volume measured by a dial scale at the back table. †On the day after operation. LLS, laparoscopic live donor left lateral sectionectomy; OLS, open live donor left lateral sectionectomy; AST, aspartate aminotransferase; ALT, alanine aminotransferase. ‡Mann–Whitney *U* test.

Table 3 Data for paediatric recipients

	LLS ($n = 11$)	OLS ($n = 11$)	P*
Preoperative data			
Age (months)	11·1(8·1)	15·7(15·6)	0·391
Sex ratio (M : F)	5 : 6	4 : 7	0·665†
PELD score	12·7(6·3)	22·9(13·4)	0·035
Postoperative data			
Minimum prothrombin time (%)	36·6(4·8)	39·7(7·9)	0·278
Peak values			
Total bilirubin (μmol/l)	105·6(28·9)	180·6(226·7)	0·577
AST (units/l)	878·2(962·0)	589·9(558·0)	0·412
ALT (units/l)	866·9 (906·7)	716·3(813·7)	0·870
1 week postop.			
Total bilirubin (μmol/l)	44·3(13·6)	28·9(13·6)	0·223
AST (units/l)	57·4(27·0)	92·7(96·0)	0·742
ALT (units/l)	93·7(58·5)	200·9(20·5)	0·341
Prothrombin time (%)	58·3(11·1)	65·6(12·1)	0·217

Values are mean(s.d.) unless indicated otherwise. LLS, laparoscopic live donor left lateral sectionectomy; OLS, open live donor left lateral sectionectomy; PELD, paediatric end-stage liver disease; AST, aspartate aminotransferase; ALT, alanine aminotransferase. *Mann–Whitney *U* test, except †Fisher's exact test.

portal vein stenosis, at 3 and 4 months, and one experienced acute rejection that was controlled by steroid pulse therapy. The three patients with stenosis of the main portal vein, below the anastomotic site, were treated by percutaneous transhepatic stent insertion. One recipient in the OLS group died 2 months after transplantation from acute severe pneumonia.

Medical costs

In Korea, total medical costs include costs paid by the insurance company and those paid by the patient. As insurance is generally provided to everyone, out-of-pocket costs to donors were compared in the present study. There was no significant difference in mean costs to donors in the LLS and OLS groups (US $5997(1131) *versus* 6100(1145); $P = 0·831$).

Discussion

Only a few centres have performed laparoscopic donor hepatectomy. This is probably because the procedure can be carried out only by surgical teams with expertise in both minimally invasive liver surgery and liver transplantation with partial and live donor liver grafts[9]. At the authors' institution more than 700 open hepatectomies, 280 LDLTs and 35 laparoscopic hepatectomies are done annually, indicating that such expertise is available for laparoscopic live donor hepatectomy. As all live donor hepatectomies in this study were undertaken by a single surgeon, there should have been no bias relating to surgical technique.

During all laparoscopic left-sided hepatectomies, the surgeon stood between the donor's legs, in the French position[4,5,9]. This position is convenient for manipulation of many laparoscopic instruments. One of the major concerns in laparoscopic hepatectomy including LLS is the choice of instruments for countertraction. The authors used atraumatic graspers, which have trauma-absorbent material on both jaws. These instruments can pull the liver atraumatically during division of the hepatic parenchyma. At this institution laparoscopic anatomical hepatic resection is always performed using the same method as for open liver surgery, including the use of a laparoscopic ultrasonic dissector. During laparoscopic donor hepatectomy, *en masse* or blind stapling of the hepatic parenchyma, to achieve meticulous haemostasis and biliostasis, cannot be performed. A 'hanging-over' manoeuvre is always used, which results in easier, more accurate hepatectomy and a better view of the left bile duct. To cut the left bile duct, a Hem-o-lok® is applied just below its targeted level. Although some bleeding may occur at the cut level of the left bile duct and hilar plate, this bleeding site can be controlled by a laparoscopic grasper with electrocautery, and subsequently sutured using Prolene® 6/0 at the back table after graft procurement. Two donors in the LLS group showed type D1 biliary anomalies, in which the right posterior duct drained into the left bile duct. To preserve the posterior duct safely, the left bile duct was cut following intraoperative cholangiography.

The donors were younger in the LLS group than in the OLS group, and ten of 11 donors in the laparoscopic group were women, suggesting that younger women desired less scarring and earlier recovery.

This study showed a small difference between preoperative and postoperative graft volume. This may be related to the usual 5 per cent difference between graft volume estimated by preoperative CT and the actual volume in the operative field, due to intrahepatic blood in the graft. Mean postoperative peak AST concentration was higher in the OLS group. This may have been because the remnant segment IV sustained ischaemic damage after left lateral sectionectomy for LDLT, which was performed routinely along the right side of the falciform ligament. In keeping with this, the hypoattenuation area in segment IV seen on postoperative CT, indicating ischaemic necrosis, was larger in the OLS group[10]. Mean hospital stay and time to normal dietary intake were shorter in the LLS group.

A major concern during surgery is the speed of graft retrieval from the abdomen. The warm ischaemia time did not differ between the LLS and OLS groups in the

present study. Although LLS took longer in the authors' initial experience, the mean duration of operation did not differ significantly between the two groups. A previous case–control study found that, compared with open resection, laparoscopic left lateral sectionectomy was associated with decreased blood loss[11]. In the present study mean operative blood loss was similar in the LLS and OLS groups.

Long-term liver graft outcome following LLS is of key importance. After kidney transplantation in young children, rates of delayed graft function and acute rejection were increased when the renal graft was harvested through laparoscopy[12]. Reasons for such renal function impairment are unclear, but the pneumoperitoneum necessary to perform laparoscopy may be associated with haemodynamic disturbance in the kidney vasculature[12]. In the present LLS group, the pneumoperitoneum did not adversely influence liver grafts, as demonstrated by recipient outcomes, although follow-up was short. There were no surgical, vascular, immunological or infectious complications specifically resulting from laparoscopic organ retrieval. The PELD score of the OLS group was higher than that of the LLS group because there were more urgent transplants in the open group. The OLS group showed worse outcomes, including two patients with portal vein stenosis, one with acute rejection and one death. Although a total of three patients in the two groups developed portal vein stenosis, this was unlikely to be related to the liver graft. Rather, it was due to recipient status, such as biliary atresia with portal vein stenosis and a smaller portal vein.

Although higher medical costs may be expected for LLS than for OLS because of the use of laparoscopic instruments, there was no difference in out-of-pocket medical costs between the two groups. The shorter hospital stay in the LLS group may have reduced medical costs.

Total laparoscopic live donor right hepatectomy is rarely performed in adult liver transplantation and has not yet been compared with open donor hepatectomy, excluding laparoscopically assisted surgery[13]. In contrast, LLS in paediatric liver transplantation is a safe, feasible, and reproducible procedure, and has been compared with open donor hepatectomy[4,5,9]. The present study has shown that LLS may be beneficial for the donor, and seems to be a safe, feasible and reproducible procedure in paediatric liver transplantation.

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Supporting information

Additional supporting information may be found in the online version of this article:

Video S1 Laparoscopic donor hepatectomy (wmv file)

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Commentary

Comparison of open and laparoscopic live donor left lateral sectionectomy (*Br J Surg* 2011; 98: 1302–1308)

The first laparoscopic liver resection was reported nearly 20 years ago, but this operation is still not a routine part of clinical practice in many units where liver surgery is undertaken. The worldwide literature contains around 3000 laparoscopic liver resections, three-quarters of which have been performed since 2006[1]. Results suggest that in experienced centres laparoscopic liver resection can be performed with equal safety and oncological efficacy to that of open surgery. No randomized controlled study comparing laparoscopic and open liver resection has been performed. A caveat at this stage of the development of laparoscopic liver surgery is the possibility of publication bias, leading to a falsely reassuring view. Other confounding factors are differences in terminology (pure laparoscopic *versus* hand-assisted *versus* hybrid surgical procedures), unknown requirements for overcoming the learning curve effect, concerns about gas embolism and the paucity of major hepatectomies in the reported laparoscopic experience[1,2].

Around 75 per cent of procedures reported worldwide have been wedge resections, segmentectomies or bisegmentectomies. Only 1·7 per cent of reported laparoscopic liver resections were live donor hepatectomies. Series focusing specifically on live donor hepatectomies have mostly comprised laparoscopically assisted procedures[3]. The first consensus conference convened in Louisville in November 2008 on the international position on laparoscopic liver surgery acknowledged that laparoscopic live donor hepatectomy is the most difficult and controversial application of laparoscopic liver surgery[2].

Against this background, the experience of completely laparoscopic live donor hepatectomy reported by the Seoul group has a small sample size, but is the largest series worldwide and provides the most authoritative view of this procedure. Success with this operation requires three key attributes: experience in advanced laparoscopic surgery, experience in liver resections and experience in living donor liver transplantation. To place it in context, in their own unit, the authors of this report perform more live donor liver transplant operations than the whole of Europe or the USA every year. In this most emotionally challenging and technically demanding of liver resections, this paper demonstrates the safety and efficacy of the laparoscopic approach, and has set a benchmark that is unlikely to be surpassed for some time.

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