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Safely Implementing a Program of Pure Laparoscopic Donor Right Hepatectomy: The Experience From a Southeast Asian Center

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Background: Laparoscopic donor right hepatectomy (LDRH) is a technically challenging procedure. There is increasing evidence demonstrating the safety of LDRH in high-volume expert centers. We report our center's experience in implementing an LDRH program in a small- to medium-sized transplantation program. **Methods:** Our center systematically introduced a laparoscopic hepatectomy program in 2006. We started with minor wedge resections followed by major hepatectomies with increasing complexities. In 2017, we performed our first laparoscopic living donor left lateral sectionectomy. Since 2018, we have performed 8 cases of right lobe living donor hepatectomy (laparoscopy-assisted: 4 and pure laparoscopic: 4). **Results:** The median operative time was 418 (298–540) min, whereas the median blood loss was 300 (150–900) mL. Two patients (25%) had surgical drain placed intraoperatively. The median length of stay was 5 (3–8) d, and the median time to return to work was 55 (24–90) d. None of the donors sustained any long-term morbidity or mortality. **Conclusions:** Small- to medium-sized transplant programs face unique challenges in adopting LDRH. Progressive introduction of complex laparoscopic surgery, a mature living donor liver transplantation program, appropriate patient selection, and the invitation of an expert to proctor the LDRH are necessary to ensure success.

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Living donor liver transplantation (LDLT) has been the solution to the chronically low deceased organ donation rates in many Asian countries. In Singapore, National University Hospital has performed the most cases of liver transplantation in Singapore. It is also the center that performed Southeast Asia's first adult-to-adult right-lobe LDLT in 1996.

With high volume of LDLTs performed in Asia, high-volume centers such as those in Korea have started performing liver donor hepatectomy using minimally invasive techniques. According to the Second Morioka international consensus conference published in 2015 and a more recent expert panel statement on laparoscopic living donor hepatectomy, laparoscopic donor left lateral sectionectomy (LDLLS) should be considered standard practice in the setting of pediatric liver transplantation.[1,2] We have also recently reported our early experience in such LDLLS with excellent outcomes.[3] In contrast, The Second Morioka consensus conference stated that pure laparoscopic donor right hepatectomy (PLDRH) should be considered an innovative procedure with a need for standardization and pointed out the current lack of evaluation of its early outcomes and its risk to benefit ratio. Subsequently, a few large volume centers, predominantly in Korea, have reported larger series of laparoscopic donor right hepatectomy (LDRH) with excellent results and outcomes, showing its safety and feasibility.[4-6]

The National University Hospital in Singapore implemented our LDRH program in October 2018. Initial cases were performed with laparoscopy-assistance (LARH), and subsequently, we performed our first PLDRH in December 2018. We have since performed a total of 8 cases (4 LARH and 4 PLDRH). In this study, we describe our journey in implementing the LDRH program with an emphasis on safety.

MATERIALS AND METHODS

Demographic and clinical data regarding donors as well as the organ recipients were collected prospectively. Outcomes, including complications and follow-up data, were also collected. Ethics approval was obtained from the National Healthcare Group Domain-specific Review Board, reference number: 2021/00874.

All donors were carefully evaluated on their liver volumetry, graft size, and anatomy of the hepatic vasculature and biliary tree. Liver volume and vascular anatomy were evaluated using multiphasic computed tomography (CT) scan and CT volumetry, whereas biliary anatomy was assessed by magnetic-resonance cholangiopancreatography. Donors with standard anatomy were selected for the initial cases. Each surgery was performed by a senior liver transplant surgeon and 2 assistants, and all transplant surgeons were involved if they were not participating in the recipient operation. Port placement for LARH is illustrated in Figure 1A, and complete mobilization of the right lobe liver graft was performed laparoscopically. The right lobe was freed from its posterior attachments and the inferior vena cava (IVC), with careful ligation and division of the short hepatic veins. Right-sided hilar structures (including the right hepatic artery [RHA] and right portal vein [RPV]) were also carefully isolated and slung with vascular loops before an upper midline incision was made. Subsequently, liver parenchymal transection was performed via the upper midline incision using an open cavitron ultrasonic surgical aspirator device. All our initial cases were right lobe grafts without the middle hepatic vein (MHV). On completion of the parenchymal transection, the graft was delivered in a sterile bag via the upper midline incision. The abdominal wound at the end of the operation is shown in Figure 1B.

In contrast, port placements for PLDRH are shown in Figure 2A. We first perform antegrade cholecystectomy and subsequently determine the "landing zone" for liver parenchymal transection. The "landing zone" refers to the intended site of landing of parenchymal transection for bile duct transection. It was marked with radio-opaque metal clips placed on the Glissonean sheath at the hepatic hilum. Intraoperative cholangiogram was performed to assess the suitability of the "landing zone," and to assess where the parenchymal transection line is with respect to the bile duct transection site to ensure optimal bile duct orifice for anastomosis without compromising the remnant structures. The right lobe of the liver was then fully mobilized off its right-sided attachments (namely the right diaphragm, right adrenal gland, and short hepatic veins between the caudate lobe and the IVC). We did not perform the right hepatic vein (RHV)/MHV tunnel laparoscopically for "hanging maneuver" in our initial series. Careful dissection of the RHA and RPV was performed, with both structures carefully isolated and slung with vascular loops. We avoided the use of Hem-o-lok clips on these structures to prevent possible interference during the bile duct division at the later steps. Indocyanine green dye (2.5 mg) was injected intravascularly after the RHA and RPV were clamped temporarily with vascular Bulldog clamp to determine the ischemic line through the PINPOINT Endoscopic Fluorescence Imaging (Stryker) system as shown in Figure 2B. This was also used at a later stage alongside intraoperative cholangiogram to visualize the biliary anatomy before division of the bile duct.

The falciform ligament was taken down and tied with a Surgitie (Covidien) and exteriorized on the patient's left (Figure 2C) to use as retraction. The laparoscopic cavitron ultrasonic surgical aspirator was used for liver parenchymal transection in all cases. In selected cases, laparoscopic ultrasonic dissector (Harmonic ACE+7, Johnson & Johnson Inc) was used to perform resection of the first 1 to 2 cm of the liver parenchyma. Additionally, laparoscopic bipolar and monopolar cautery devices were used to facilitate hemostasis during the operation. During parenchymal transection, the segment V and VIII tributaries of the MHV were carefully isolated and ligated in preparation for reconstruction at the back-table process (Figure 2D). After the careful division of the caudate lobe parenchyma, the right hepatic duct (RHD) was isolated at the predetermined "landing zone" (care was

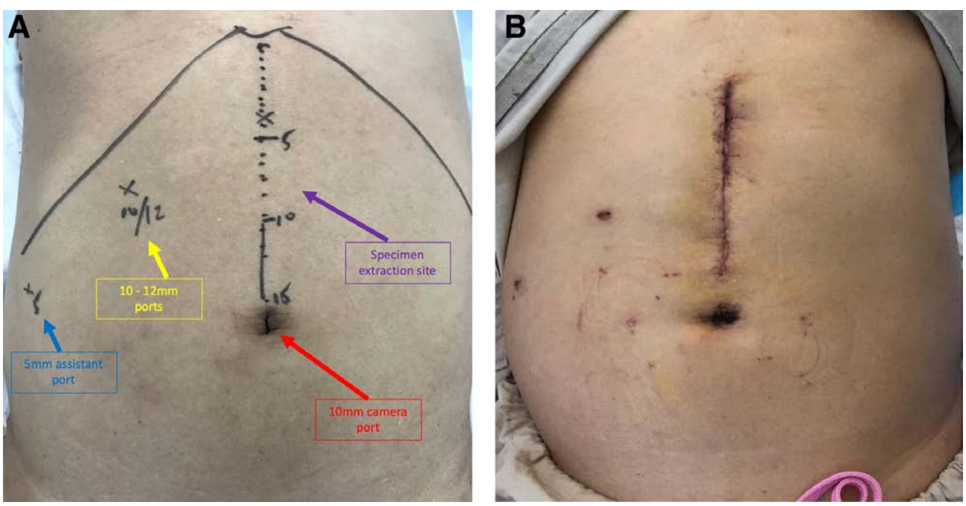

FIGURE 1. Surgical incisions in LDRH. A, Port placement for LDRH. B, Abdomen after LDRH. LDRH, laparoscopic donor right hepatectomy.

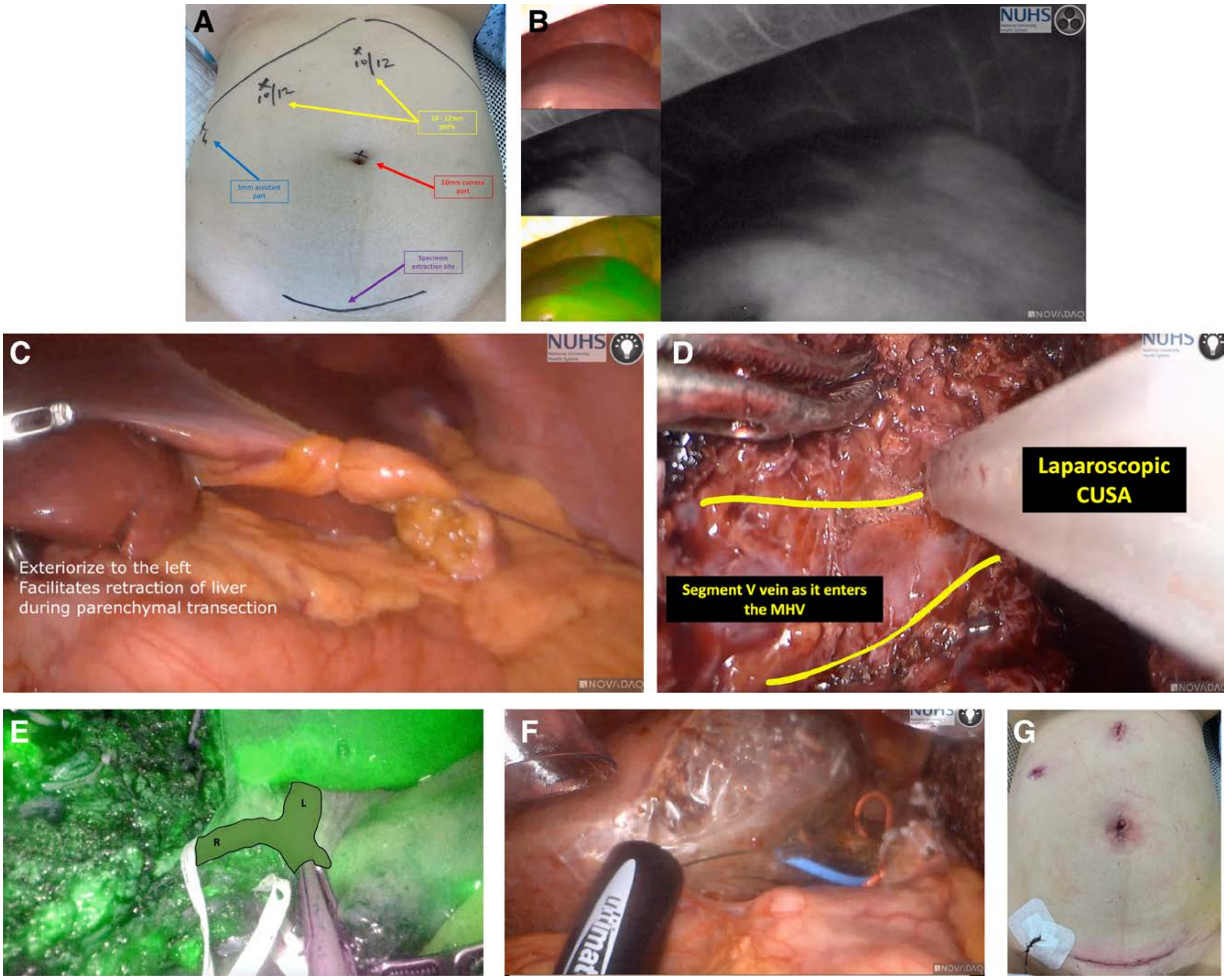

FIGURE 2. A, Port placements for PLDRH. B, Indocyanine green injection with right inflow clamping demonstrating ischemic line. C, Surgitie exteriorized to provide traction. D, Laparoscopic isolation of segment V vein. E, Biliary confluence as seen with indocyanine green. F, Graft in a specimen bag with vessels undivided. G, Abdominal incisions after PLDRH. CUSA, cavitron ultrasonic surgical aspirator; MHV, middle hepatic vein; PLDRH, pure laparoscopic donor right hepatectomy.

taken to completely free the right side of the MHV up until three-quarters of its length to avoid injuring the posteroinferior aspect of the MHV, which can result in massive bleeding). The use of intraoperative indocyanine green is helpful in identifying the biliary confluence as shown in Figure 2E. After the division of the RHD, the donor RHD stump was secured with either two 10-mm Hem-o-lok clips or with a continuous 5/0 polydioxanone suture in 2 layers. Completion cholangiogram was performed using intraoperative x-ray cholangiogram to ensure continuity of the donor biliary system. The liver parenchymal transection was completed with the entire anterior surface of the IVC visualized, with subsequent careful isolation of the RHV. The right hepato-caval ligament was also clipped and divided. Upon completion of all these crucial steps, the right lobe graft was ready to be procured. A small Pfannenstiel incision (10–12 cm depending on graft size) was made with the linea alba exposed along the midline. An Alexis wound protector was placed with a glove port and a 15-mm port was inserted through the glove port to maintain pneumoperitoneum. A 15 mm specimen bag was inserted and the right lobe graft was placed in the bag with all the vascular structures intact as shown in Figure 2F. When the graft was ready to be removed, the RHA (double clipped with 5-mm Hem-o-lok), RPV (double clipped with 10-mm Hem-o-lok), and RHV (Ethicon ATW 45-mm vascular stapler) were secured and divided in this sequence. The specimen bag was closed, and the graft was retrieved via the Pfannenstiel incision. The immediate postoperative incision for PLDRH is shown in Figure 2G.

All patients were placed on the hospital enhanced recovery after surgery pathway. Analgesia comprised intravenous paracetamol and patient-controlled analgesia with either morphine or fentanyl as decided by the attending anesthetist. Postoperatively, all patients were reviewed by the physiotherapist on postoperative day 1 for early ambulation. All indwelling urinary catheters were removed by postoperative day 1 if there were no medical contraindications. We do not perform routine postoperative imaging for our donors. Should there be concerns of vascular complication as suggested by deranged liver functions in an unwell patient, as indicated by grossly abnormal laboratory markers such as coagulation profile, serum lactate, and transaminases so further evaluation will be performed with imaging modalities such as an ultrasound Doppler or a CT scan of the liver.

TABLE 1.

Donors and liver graft characteristics

Donor number	Technique	Age, y	BMI, kg/m²	Total liver volume, mL	Graft volume (based on CT volumetry), mL	Actual graft weight, g	Blood loss, mL	Bile duct orifice, n	Operative time, min
1	LARH	52	24.5	1055	707	680	600	1	435
2	LARH	41	22.6	1453	959	664	500	1	391
3	PLDRH	29	21.2	1364	767	733	150	2	401
4	LARH	48	26.6	1255	798	510	300	2	391
5	PLDRH	28	36	1083	728	935	900	1	540
6	PLDRH	40	26.3	1666	1111	980	300	1	484
7	PLDRH	40	19.7	949	622	409	200	1	472
8	LARH	49	25.6	1242	862	843	250	1	298

BMI, body mass index; CT, computed tomography; LARH, laparoscopic-assisted donor right hepatectomy; PLDRH, pure laparoscopic donor right hepatectomy.

RESULTS

Four LARH and 4 PLDRH were performed during the study period. Baseline donor characteristics, CT volumetry data, and operative metrics are shown in Table 1. Two of 8 donors (25.0%) had a drain placed intraoperatively. The median operative time was 435 (391–40) min, while the median blood loss was 300 (150–900) mL. None of the donors required perioperative blood transfusions.

Postoperative biochemical and functional results are shown in Table 2. All donors except 1 were ambulant on postoperative day 1 and were all cleared to be independently ambulant by a physiotherapist by postoperative day 4. The median total warm ischemia time and cold ischemia time were 42 (34–75) min and 66 (53–105) min, respectively.

Median postoperative day 1 pain score at rest (measured via visual analog scale) was 2 (0–6), and pain score on movement was 2 (1–9). Median days to the first bowel movement was 5 (3–6) d and the median time to ambulation was 1 (1–3) d. The median donor length of stay was 5 (3–8) d and the median time to return to work was 55 (24–90) d. None of the donors sustained any long-term morbidity from surgery.

In the recipient group, 2 of 8 patients (25.0%) developed biliary strictures that required biliary intervention 6 mo after surgery (1 patient with endoscopic retrograde cholangiopancreatography stenting and another with percutaneous biliary stenting).

TABLE 2.

Biochemical and functional outcomes

Donor number	1	2	3	4	5	6	7	8
Biochemical outcomes								
Day 1 bilirubin level, mg/L	61	69	53	36	31	132	36	25
Day 1 AST, IU/L	330	358	458	211	998	162	377	132
Day 1 ALT, IU/L	394	463	603	298	1032	243	431	93
Day 3 bilirubin level, mg/L	107	110	74	44	41	79	63	64
Day 3 AST, IU/L	86	211	362	70	168	66	153	73
Day 3 ALT, IU/L	198	463	219	198	302	146	295	58
Day 5 bilirubin level, mg/L	105	78	19	52	20	38	43	77
Day 5 AST, IU/L	83	194	50	131	71	111	105	110
Day 5 ALT, IU/L	155	156	94	188	156	137	215	70
Functional outcomes								
Length of stay, d	5	5	3	3	8	6	5	4
Ambulation, d	1	1	1	1	2	1	1	1
POD 1 ambulation distance	10	80	30	100	0	50	50	60
POD 2 ambulation distance	60	80	200	200	100	80	200	100
POD 3 ambulation distance	80	200	200	200	140	200	200	200
POD 4 ambulation distance	200	200	200	200	200	200	200	200
POD 5 ambulation distance	200	200	200	200	200	200	200	200
Return to work, d	61	24	62	25	90	55	55	25

ALT, alanine aminotransferase; AST, aspartate aminotransferase; POD, postoperative day.

DISCUSSION

The benefits of the laparoscopic approach for donors are now well established in pediatric donations, with a laparoscopic approach now considered the standard of care.[1,2,7] Earlier consensus statements called for caution in LDRH, especially in donors with non–standard anatomy.[2] The concerns regarding widespread adoption of LDRH stem from the lack of more robust data regarding the safety of this innovative donor operation as well as the impact on the donor graft, which is inextricably linked to recipient outcomes. Although a number of initial reports, including a series of 55 donors by Suh et al[8] from Korea, reported comparable outcomes between LDRH and open donor right hepatectomy (ODRH), subsequent reports by Park et al[9] and Rhu et al,[6] which involved 91 and 100 LDRH respectively, showed a significant increase in complication rate in LDRH compared with open surgery, especially in the first 25 cases. Larger series, mainly from South Korean centers, have suggested that the initial results of LDRH are comparable with ODRH when performed by surgeons with sufficient experience.[10] A recently published international series, including 412 cases of minimally invasive donor right and left hepatectomy, showed favorable early outcomes across 10 experienced high-volume transplant centers.[11] In fact, a recent publication reported the extent of adoption of LDRH across the world with a total of 1587 minimally invasive donor right hepatectomies, with 48.9% being fully laparoscopic, and although Asia contributed most of this experience, there is increasing adoption of LDRH in other parts of the world.[12] A recent international consensus statement from the International Laparoscopic Liver Society concluded the safety of LDRH with no deaths reported, better short-term outcomes, and quality of life – with strong recommendations for LDRH considering these aspects.[13] Yet, although large centers have confirmed the technique's safety, these results are not easily reproducible in small- to medium-sized centers. Authors evaluating the learning curve in LDRH have reported conflicting results. Lee et al compared the learning curve of LDRH and ODRH using operative time, and showed that operative time for LDRH stabilized after approximately 15 cases. Using similar analysis, they also concluded that the learning curve for ODRH was 17 cases.[14] This is in stark contrast to the learning curve of 50 cases, which was suggested by Rhu et al,[15] a challenging requirement in small- to medium-sized centers. However, results from our initial experience demonstrate that small- to medium-sized liver transplant centers can safely mount the learning curve for LDRH with a systematic and methodical approach.

In addition to the usual requirements for laparoscopic major hepatectomy, additional considerations in LDRH include the need for meticulous preservation of crucial structures, such as the graft hepatic artery, portal vein, and outflow hepatic vein tributaries. Laparoscopic techniques in the healthy donor may theoretically result in shortened vessel lengths available for use in anastomosis because of the use of vascular clips or vascular staplers when compared with open procedures.[16] This technical drawback has not been shown to impact liver graft implantation in large series. By first understanding these considerations, a center can start working toward adopting minimally invasive surgery donor hepatectomy. It is crucial that the center must have significant experience in LDLT donor hepatectomy and minimally invasive surgery hepatectomies before adopting LDRH. A stepwise progression is also recommended by Expert Consensus Statement on Laparoscopic Living Donor Hepatectomy, starting with laparoscopic LLS for pediatric LDLT, followed by LARH, and finally LDRH.[2]

At our hospital, a systematic strategy was adopted to gradually build our laparoscopic hepatectomy program concurrently with the liver transplantation program. From January 2006 to February 2021, our unit performed a total of 329 laparoscopic liver resections. The most common operation was laparoscopic left lateral sectionectomy (n = 63; 19.1%). The overall rate of conversion was 8.2% (n = 27). Of all liver resections, major resections comprised 43.8% (n = 144). Before the first laparoscopic donor hepatectomy, we performed the first case of laparoscopic associating liver partition and portal vein ligationand laparoscopic central hepatectomy in 2015. Subsequently, the first case of LDLLS was performed in 2017.[3] After establishing our experience of 5 cases of LDLLS, the first 2 cases of minimally invasive donor right hepatectomy were LARH performed in 2018. LARH, which was first reported by Koffron et al,[17] has been shown in multiple reports to have benefits over ODRH with regard to patient recovery and is safe and feasible.[18-22] The learning curve of LARH is relatively short compared with LDRH given its technical simplicity.[10] LARH was a good intermediate step for our transition from LDLLS to LDRH—a similar step-wise approach as that described by Takahara et al[23] in performing LDRH.

Careful donor selection is essential to ensure donor safety in an LDLT program, especially at the start of the learning curve when adopting a new procedure. Many LDRH programs have strongly advised to adhere strictly to the selection of donors with standard and simple anatomy to ensure both donor and recipient safety by simplifying an already complex donor operation. Another consideration is graft weight, and various authors have suggested that a graft weighing >600 g could also increase the difficulty of the procedure.[16,24] Although we were not restrictive in the size of the graft, we were cautious of the potential challenges a large graft may present. Although most of our cases went smoothly as the donors were carefully selected, case 5 posed a challenge as the donor had a body mass index of 36 kg/m^2 with a large right lobe graft. As such, mobilization of the right liver graft during the laparoscopic phase of LARH was difficult. The subsequent liver parenchymal transection was also made more difficult because of the donor's body habitus. Finally, our center engaged a mentor to proctor the program in developing the LDRH program. Through the transfer of skills from a surgeon with vast experience in the procedure, the learning curve can be accelerated. Our unit engaged Professor Olivier Soubrane as a mentor to further refine the LDRH technique in our center. Cases 6 and 7 were performed under his mentorship.[7,16,25,26] Unsurprisingly, the use of proctorship was strongly recommended to implement and standardize surgery as well as to shorten the learning curve in the recent International Laparoscopic Liver Society consensus statement.[13]

Apart from donor safety, the impact of an LDRH program on recipients must be considered. The true impact of LDRH on recipients has yet to be fully examined in large series. As stated above, because of the technical requirements of laparoscopic surgery, the vasculature and biliary structures, which are crucial for reconstruction and anastomosis, may be shortened compared with ODRH. This may transfer the risk of complications from the donors via the graft to recipients. Although some reports demonstrated no compromise to the integrity of the subsequent liver graft, others have commented otherwise, especially regarding biliary complications.[16,27,28] In a series of 70 cases of LDRH at Samsung Medical Center, Park et al, in a propensity score analysis with open donors, showed an increase in complications especially at the start of the learning curve.[29] However, other series have reported comparable results for LDRH recipients compared with open surgery.[8,30-32] In our series, none of the recipients suffered 90-d mortality. Biliary complications were the most common complication, affecting 2 patients (25.0%) as mentioned above.

Although large centers continue to push the boundaries of what is considered possible, with recent reports of LDRH in patients with portal vein[33-35] and biliary anatomical variations,[36] small- to medium-sized transplantation programs face different challenges. Specifically, in attaining and then maintaining competency in complex laparoscopic procedures such as LDRH with significant learning curves in a low-volume setting. A conscious effort and planned progression of cases starting from simple laparoscopic wedge resections to major laparoscopic resection and subsequently to DLLLS and LDRH with a constant team is required to maintain donor/patient safety throughout the process.

CONCLUSION

Small- to medium-sized liver transplantation programs face unique challenges in progressing toward advanced laparoscopic donor operations such as LDRH. A deliberate effort must be made to adopt a systematic approach to gain proficiency in both LDLT and complex MIS hepatectomies. Gradual increase in the complexity of laparoscopic procedure (using both hybrid and fully laparoscopic procedures) to mount the LDRH learning curve while maintaining donor safety will lead to a successful LDRH program.

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