Pure laparoscopic living donor hepatectomy: learning curve, technical pearls and pitfalls

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Abstract: Living donor liver transplant (LDLT) has markedly reduced waiting list mortality and expanded access to life-saving therapy for thousands across the globe. Application of minimally invasive surgery to donor hepatectomy has been markedly slower than in many other aspects of surgery. For donors undergoing hepatectomy, many long-lasting issues related to donation appears to involve the large incision typically used for donor hepatectomy. This has provided significant motivation for a minimally invasive approach to donor hepatectomy. Pure laparoscopic donor hepatectomy was initially reported in 2002 but adoption has been slowed by concerns about hemostasis, donor safety and recipient outcomes. Highly select centers have successfully developed minimally invasive living donor programs and have been reporting outcomes and techniques utilized. We review the technical approaches have been learned by early adopters. We discuss some of the pitfalls and challenges associated with laparoscopic donor hepatectomy. We discuss the reported experiences with the learning curve for this complex operation. We discuss the future of minimally invasive surgery for donor hepatectomy.

Keywords: Living donor; hepatectomy; laparoscopy; liver transplantation

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Introduction

Living donor liver transplant (LDLT) was successfully developed after experience with reduced sized grafts and high pediatric waitlist mortality in the 1980s (1). First performed in 1989 using left lateral sections (LLS), LDLT eventually included hemi-hepatectomies for adult recipients (2-4). Use of living donors for transplantation has required careful balance with consideration of donor risk (5).

Donor hepatectomy has been associated with excellent short-term outcomes (6). However, significant donor morbidity can occur with the large incision used for most open donor hepatectomies. At least 30% to 50% of the complications of LDLT appear to be related to abdominal wall trauma, including hernia, bowel obstruction, and chronic abdominal discomfort (7). Furthermore, many of the chronic or longer issues that liver donor face may be related to abdominal wall trauma rather than liver mass or function. This has provided significant motivation for a minimally invasive approach to donor hepatectomy.

Laparoscopic procurement of the LLS for LDLT was first reported in 2002 (8). The adoption of minimally invasive techniques in liver donor surgery has been markedly slower than in kidney. Concerns about hemostasis and safety limited application of minimally invasive surgical (MIS) techniques to donor hepatectomy. Within 10 years of the first laparoscopic donor nephrectomy, minimally invasive techniques were routinely applied for donor nephrectomy (9). However, laparoscopic donor hepatectomy remained isolated to a handful of liver transplant centers despite multiple reports indicating that pure laparoscopic approach to LLS donor hepatectomy was equivalent to open approach (10-14). Although MIS was extended to hemi-hepatectomies in 2006 (15) purely laparoscopic approach to hemi-hepatectomies would take more than 10 years from Cherqui *et al.*'s report and nearly 20 years from Ratner *et al.*'s report on laparoscopic donor nephrectomy (16,17). Several series in 2013 described hemi-hepatectomies performed via pure laparoscopic approach (18-20). A reduction in post-operative analgesia, ileus, length of stay, improved patient satisfaction, and earlier return to work has been demonstrated in some MIS series (21-23). In 2014, Morioka consensus conference in 2014 acknowledged laparoscopic LLS as the standard of care but cautioned that hemi-hepatectomy should be reserved for expert centers (24).

Since then, laparoscopic living donor hepatectomy has continued to steadily expand but remains utilized at a minority of LDLT centers throughout the world. The number of publications has increased with 7 publications between 2002 and 2007 to 66 in the past 5 years. We aim to review the cumulative published experience related to the learning curve as well as technical pearls and pitfalls that have been identified by groups with significant experience in performing PLDH.

Technical pearls

The complexity of PLDH requires an experienced team, advanced laparoscopic equipment and a significant surgical skillset. The development of technology has facilitated the growth of MIS liver surgery and PLDH. Enhanced laparoscopy is widely considered to facilitate laparoscopic liver surgery either in the 4K platform or 3D. The 3D flexible scope improves visualization, knot tying and dissection speed in PLDH. A significant reduction in operative time with the 3D technology in laparoscopic liver resection when compared with retrospective 2D controls has been described (25). Several Korean and an American group performing PLDH employ this technology and report its benefit in their experience (19,26,27).

Port placement is critical to a safe and efficient PLDH. Optimizing reach and angle can avoid damage to the graft itself and streamline surgeon ergonomics. One group described their experience and evolution port placement, as well as the challenges encountered with misplacement of each, such as difficult access to vital structures, suboptimal axis of control for inflow, or fighting between instruments (28).

Laparoscopy is dependent on a hemostatic field. Blood in the operative field absorbs light and diminishes visualization. Suction devices cannot be used continuously as they lessen pneumoperitoneum and reduce the operative field. Thus, bleeding has a dramatic impact on progression and makes the operation more difficult. Intermittent hepatic inflow occlusion is associated with lower blood loss in the donors and no difference in liver function (29). Many centers performing laparoscopic donor hemi-hepatectomy use intermittent Pringle maneuver to facilitate parenchymal transection and every laparoscopic liver surgeon should have a quick technique to gain inflow control. In our program, we utilize a Satinsky clamp inserted into the LLQ to gain inflow control. Other techniques that can be used for inflow occlusion include bulldog clamps, umbilical tape through a chest tube (30), straight vascular clamp in the LUQ.

The most common instrument for parenchymal transection is laparoscopic Cavitron Surgical Aspirator (CUSA Excel; Valleylab, Boulder, Colorado, USA). The ultrasound waves generate energy to fragment and aspirate parenchymal tissue. It is usually used in conjunction with an energy device such as bipolar cautery. This allows for a controlled laparoscopic transection and helps in minimizing blood loss. As mentioned above, blood within the field hinders visualization in a laparoscopic case as it absorbs light requiring meticulous hemostasis throughout the case (31). Our group prefers an articulating bipolar device such as the Caiman (Aesculap, Tuttlingen, Germany) to facilitate liver mobilization and hemostasis.

Our group and others have used modifications of the hanging maneuver performed with umbilical tape, plastic tubing or Goldfinger retractor (Ethicon Endosurgery, Cincinnati, OH, USA) depending upon the group's preference (30). This maneuver also assists in accuracy in defining the transection plane.

Biliary imaging both pre-operatively and intra-operatively is critical to minimize biliary complications of both donor and recipient. It is important to have intra-operative cholangiography to ensure the optimal transection plane (32,33). Whether indocyanine-green fluorescence cholangiography (ICG) or traditional contrast cholangiography is used, currently is a matter of surgeon preference (19,23,32,33).

Patient selection is also paramount to a successful PLDH program. Early in the PLDH experience at one center, complications were more likely in donors with vascular and biliary anomalies (34). This is not uniform and the highest experienced center has reported good outcomes with patients with anatomic variants rate (34-36). It is reasonable that donors with variant anatomy not be selected until adequate experience has been achieved in PLDH (37).

Pitfalls

The liver's lack of external landmarks and the nonlinear plane of transection in a donor hepatectomy increase the risk of technical errors. Additionally, the ideal liver retractor is more similar to a human hand than a laparoscopic grasper. Large livers can be difficult to retract and vulnerable to capsular injury. Thus some centers advocate restricting laparoscopic donor hepatectomy to smaller livers (38).

The precision required in defining the transection plane in donor surgery to optimize graft anatomy and avoid remnant bile leak is a key component of both open and laparoscopic donor hepatectomy. Laparoscopic magnification may enhance visualization and identification of bile leak but testing for bile leaks is more challenging laparoscopically. Bile leaks with laparoscopic suturing have been reported (34) and many laparoscopic donor programs feel that clipping provides the most watertight occlusion of the remnant duct stump. Biliary stricture can also occur in the donor and has been reported (34). Donor vascular complications have occurred and are often due to variant anatomy and as discussed above donors with variants anatomy are most appropriate for centers with the most experience of laparoscopic donor hepatectomy (10-12,34,39).

Recipient complications must also be considered and use of staplers particularly bilateral staplers have raised concerns about vessel length. Graft quality in PLDH has been shown to be similar to open though in some early experiences multiple bile ducts were encountered (23). Utilization of staplers for vascular transection does shorten the graft vasculature and requires expertise for reconstruction (36). Recipient artery complications have been rare and thought to potentially be due traction injury due to manipulation laparoscopically with lack of tactile feedback or thermal injury due to CUSA or energy (27). Vein length can be addressed using extension grafts (40).

Learning curve

Laparoscopic donor hepatectomy requires experience in donor hepatectomy as well as laparoscopic liver surgery. Laparoscopic hepatectomy has been shown to have a long learning curve of 45–60 cases (41). All of the groups that have developed PLDH had accumulated extensive experience with hundreds of procedures in open donor liver surgery and laparoscopic liver surgery prior to embarking on laparoscopic donor program development. With this experience still, the published learning curves for PLDH ranged from at least 15–20 for LLS (11,42) to 60 procedures for major LDH emphasizing the complexity of this operation (37). The most recent report using a CUSUM analysis determined the learning curve for right-sided PLDH to be 70 cases, with an extensive experience in living donor hepatectomy and laparoscopic hepatectomy up front suggesting an even more substantial curve (43).

In each of the published series, operative time, warm ischemic time and blood loss generally decrease over time and the largest series generally report fewer major complications including vascular and biliary complications later in their experience (26,27,34,44). In many of these, the authors report an alteration in technique after encountering complications, for instance, remnant bile duct closure with suture, metal clip or Hem-o-Lock clip, or the use of ICG cholangiogram after biliary complications. This evolution in technique inherent to development of novel procedures warrants caution in interpreting complication rates and operative times.

It is unclear whether learning curve data from early adopters who are primarily self-taught will be generalizable to other groups. As the technique become more standardized, it may be that learning curves will be shortened. However, living donor and laparoscopic liver surgery requires coordination of a large team that may include junior surgeons, surgical trainees, circulating nurses, scrub nurses and OR technicians. The experience of each team member can impact operative time and perhaps even outcomes.

Future directions

Minimally invasive application to living donor hepatectomy appears to be growing significantly. In addition to conventional laparoscopy, the robotic platform has been increasingly utilized for hepatectomy as surgeons gain experience. The first donor robotic hepatectomy was reported in 2011 in a hybrid fashion (45). A series of thirteen pure robotic donor hepatectomies was reported in 2016 with excellent outcomes (46) including acceptable warm ischemic time and comparably low rates of vascular and biliary complications in the recipients. ICG is built-in to the system making its use easier and more dynamic throughout the robotic case. Wider adoption of robotic living donor hepatectomy has been limited by the lack of tools for parenchymal transection primarily the ultrasonic aspiration.

Proctoring and mentoring have been integral the dissemination of experience in MIS living donor hepatectomy amongst centers throughout the world; yet, there are so few first generation PLDH surgeons that the creation of formalized training programs is not possible. Continuing the trend of proctoring and mentoring will be necessary to ensure quality and diffusion of best practices as more centers develop laparoscopic living donor programs.

Experience in pure laparoscopic donor hepatectomy is increasing at select centers. The technical difficulty, steep learning curve and requirement for donor safety and excellent recipient outcomes should encourage the exchange of lessons learned at these highly specialized institutions throughout the development of a PLDH program. Challenges for diffusion of this technique are significant but surmountable.

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Footnote

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