

# Learning curve in laparoscopic liver surgery: a fellow's perspective

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**Abstract:** The learning curve for laparoscopic liver surgery is infrequently addressed in current literature. In this paper, we explored the challenges faced in embarking on laparoscopic liver surgery in a unit that did predominantly open liver surgery. In setting up our laparoscopic liver surgery program, we adopted skills and practices learnt during fellowships at various high volume centers in North America and Australia, with modifications to suit our local patients' disease patterns. We started with simple minor resections in anterolateral segments to build confidence, which allowed us to train the surgical and nursing team before progressing to more difficult resections. Inter institutional collaboration and exchange of skills also enabled the synergistic development of techniques for safe progression to more complex surgeries. Multimedia resources and international guidelines for laparoscopic liver surgery are increasingly accessible, which further guide the practice of this emerging field, as evidence continues to validate the laparoscopic approach in well selected cases.

**Keywords:** Colorectal liver metastases; hepatocellular carcinoma (HCC); laparoscopic liver resection (LLR); learning curve; liver cancer

Submitted Feb 10, 2015. Accepted for publication Jun 04, 2015.

doi: [10.3978/j.issn.2304-3881.2015.06.07](https://doi.org/10.3978/j.issn.2304-3881.2015.06.07)

View this article at: <http://dx.doi.org/10.3978/j.issn.2304-3881.2015.06.07>

***“If I have seen further than others, it is by standing on the shoulders of giants.”***

**—Sir Isaac Newton**

Since the 1<sup>st</sup> report by Reich in 1991, there has been exponential growth in the interest and practice of laparoscopic liver resections (LLR) worldwide. Initially, only wedge resections and minor hepatectomies were attempted (1). However, with increasing experience, better optics and instrumentation, leading surgeons from large academic centers have been performing major hepatectomies, anatomical posterior segment resections, pure donor hepatectomies, and complex combined resections, such as combined major hepatectomy with pancreaticoduodenectomy laparoscopically.

Few reports, however, address the issue of mounting the learning curve in the transition from simple laparoscopic resections to more complex operations. Understandably, the learning curve for laparoscopic liver surgery is difficult to

document. The techniques for liver resection differ widely depending on the location and size of the lesion, the need for parenchymal preservation versus anatomical resection, the underlying parenchymal consistency and method of preferred parenchymal transection. Furthermore, there may be the need for concomitant gastrointestinal or major vascular resection.

Each surgeon's learning curve may be influenced by his or her training background, depending on whether it is from open liver surgery to the laparoscopic approach, or from advanced laparoscopic surgery transitioning to liver surgery. For the open liver surgeon, mastering laparoscopic liver surgery can be a challenge especially with laparoscopic suturing and change in view from the anterior-posterior view of traditional open liver surgery to the caudal-cranial view of laparoscopy. In contrast, the challenge the laparoscopically trained surgeon faces may be understanding liver anatomy and its complex variations which may present a formidable initial learning curve.

Vigano *et al.* described their learning curve experience, dividing their experience into three groups of 58 patients each, who underwent LLR between 1996 and 2008 (2). In their paper, there were progressive improvements in the conversion rate, operative time, blood loss and morbidity over the time periods. Using conversion rate as their primary outcome (with adjustment for risk factors), they concluded that a learning curve of about 60 patients was required for minor hepatectomies. Abu Hilal *et al.* on the other hand suggested that improvements in the operative time and median hospital stay could be achieved after only 15 cases for their standardized procedure of laparoscopic left lateral sectionectomy (LLS) (3). In a recent article, Spampinato *et al.* demonstrated a single surgeon learning curve of only ten cases of major/complex totally LLR with improvements in operative time, median blood loss, transfusion requirement and need for intermittent Pringles maneuver. He attributes this to a solid foundation of advanced training in hepatobiliary and transplant surgery coupled with a fellowship in a high volume tertiary center specializing in laparoscopic and advanced hepatobiliary surgery (4). We recently published our initial experience in LLR and demonstrated that individual surgeon and institution volume were the main risk factors for open conversion after laparoscopic minor hepatectomy during the learning phase, albeit individual surgeon experience was the more significant factor (5). In this experience, based on conversion rates, the learning curve for an individual surgeon was about 15-20 cases for laparoscopic minor liver resection, which was lower than that reported by early studies but similar to more recent studies (2,5,6). This may suggest that with the rapid advancements in surgical technique and equipment for left hemihepatectomy (LH), the learning curve may be shortened when the surgeons collectively share their experience and actively help each other as a team in different phases of each individual's learning period. *Table 1* summarizes several studies on the learning curve for laparoscopic liver surgery.

One of the earliest LLR reported from an Eastern Hepatopancreatobiliary (HPB) unit was by Hashizume and colleagues from Japan in 1995. Here he reported a cirrhotic patient who successfully underwent laparoscopic resection of a 2 cm hepatocellular carcinoma (HCC) in Segment 5 (15). One of the first case series reported from Japan was from Kaneko and colleagues: a series of 11 patients who underwent laparoscopic partial hepatectomy or LLS with only one conversion for bleeding (16). He went on to describe the learning curve for these operations, with an

improvement in operative times between the early period [1993-1998] and the later period [1999-2004] (17).

The Louisville consensus statement in 2008 provided international guidelines for laparoscopic liver surgeons and the recently concluded 2<sup>nd</sup> consensus conference held in Iwate in 2014 further added important evidence with regards to the practice and adoption of this emerging field (18,19). It was recommended in the 1<sup>st</sup> consensus statement that LLR be limited to solitary lesions (5 cm or less), in anterior segments of the liver (Segments 2,3,4b,5,6) with LLS being standard practice. In the latest consensus from the Iwate meeting, this limitation was cautiously expanded to include all minor resections being standard practice although these are generally taken not to include the "difficult" segments (Segments 1,4a,7,8). There was also a clear trend towards increasing proportion of major resections and complex resections being performed around the world with fewer conversions. Although the level of evidence was still low, it was concluded that in majority of parameters studied, the outcomes were at least not inferior in margin negativity, morbidity, perioperative mortality and overall survival. Furthermore, benefits of minimally invasive surgery (MIS) were seen with superior pain, cosmesis, blood loss and length of stay (19). While most of the evidence for LLR was based on studies without randomized control trials, they consistently show better short-term outcomes without compromise on long-term oncological outcomes. There are two randomized controlled trials underway in Norway (Oslo-CoMet) and Netherlands whose results should give us more insight on these issues (20).

The benefit of being a young laparoscopic liver surgeon in this generation is the availability of literature and videos to learn techniques, compared to our pioneering colleagues. In contrast to the lack of standardized techniques in the early years, there are currently good published techniques on the more common resections such as the LLS and even major hepatectomies (7,21). With increasing experience, technical tips on difficult resections such as isolated posterior segment resections (Segments 7/8), central hepatectomies and caudate resections are being shared (8,22-24). Laparoscopic donor hepatectomy techniques have also been described, although these surgeries are understandably performed only in a handful of high volume transplant centers (25). These are important adjuncts in helping to overcome the learning curve. However, it is important that adoption of these techniques is guided by an experienced surgeon.

Progressing to the more difficult resections should only

**Table 1** Summary of laparoscopic hepatectomy studies mentioning learning curve

Author/year	Study origin	Patient number	Type of resection	Pathology	No. of patients before improvement	Parameters of improvement
Chang <i>et al.</i> 2007 (7)	W	36	LLS	Mixed	18	Operating time improved; less portal triad clamping (use and duration)
Abu Hilal <i>et al.</i> 2008 (3)	W	30	LLS	Mixed	15	Operative time improved; median hospital stay shorter
Otsuka <i>et al.</i> 2009 (8)	E	88 (90 cases)	Mixed	Mixed	45	Higher proportion of PS segments/malignancy attempted; less blood loss and shorter hospital stay
Vigano <i>et al.</i> 2009 (2)	W	174	Mixed	Mixed	60 (minor hepatectomies)	Conversion rate, operative time, blood loss, morbidity improved; less pedicle clamp applied/time used
Cannon <i>et al.</i> 2011 (9)	W	300	Mixed	Mixed	100	Operative time improved; similar blood loss, morbidity and mortality despite increase number of segments/repeat hepatectomies
Troisi <i>et al.</i> 2011 (10)	W	36	LLS	Mixed	10	Shorter operative time, less blood loss (NS)
Robinson <i>et al.</i> 2012 (11)	W	37	Mixed	Mixed	18	Attempted more right sided resections; fewer conversions
Spampinato <i>et al.</i> 2014 (4)	W	24	Major/complex	Mixed	10	Operative time, median blood loss, percentage requiring pedicle clamping, median units blood transfusion improved
Chan <i>et al.</i> 2014 (12)	E	98 (100 cases)	Mixed	Mixed	50	Similar operative time, blood loss despite more major resections
Goh <i>et al.</i> 2014 (5)	E	147	Minor	Mixed	15-20	Individual surgeon and institution volumes were important factors associated with open conversion after Laparoscopic minor hepatectomy
Cai <i>et al.</i> 2014 (13)	E	365	Mixed	Mixed	15-43	Stabilization of mean blood loss and operative time
Liu <i>et al.</i> 2014 (6)	E	41	LLS	Mixed	20	Median operative time and blood loss
Choi <i>et al.</i> 2015 (14)	E	46	LLS, LH, wedge PS segments	Mixed	10	Stabilized operative time and blood loss

W, Western studies; E, Eastern studies; LLS, left lateral sectionectomy; LH, left hemihepatectomy; PS, posterosuperior; NS, not significant.

be attempted after sufficient experience in the simpler resections. Cho *et al.* compared the outcome after LLR of HCC situated in the antero-lateral segment (Segments 2,3,5,6 and 4b) *vs.* those in the postero-superior segment (Segments 1,4a,7 and 8), and found that patients with postero-superior segments resected had longer operative time and a tendency towards longer median hospital stay

and greater rate of intraoperative transfusion, but with no significant difference in postoperative complications or cancer recurrence (22). A recently published multicenter study in Japan on case selection for pure LLR considered scoring the difficulty of the resection according to low, intermediate and high. This score was calculated based on tumor location, extent of liver resection, tumor size,

proximity to major vessel and liver function to provide a score from 1-10 (26). Although yet to be validated by other centers outside of Japan, this paper provided a novel and practical method for predicting the technical difficulty for LLR and may provide a framework to choose resections that they can do laparoscopically consistent with their experience. In the latest consensus statement from Iwate, there was strong recommendations from the jury and expert panel that the validation and application of this novel system be carried out together with a structured training program for further safe adoption of laparoscopic liver surgery.

### Personal experience

Coming from a background of predominantly open liver surgery, I decided to embark on an international fellowship in a large tertiary referral center in Australia known for its work in laparoscopic liver surgery. My supervisor Dr. Nicholas O'Rourke, and his unit at the Royal Brisbane Hospital was one of the first to publish their technique of laparoscopic right hepatectomy (27). Since 1999, they have developed an extensive experience in laparoscopic liver surgery, with over 340 laparoscopic resections to date (28,29). There was a good case mix of advanced laparoscopic hepatectomies, laparoscopic pancreatic surgery as well as complex minimally invasive biliary surgery in my training year. During my fellowship, besides laparoscopic hepatobiliary surgery, I was also exposed to advanced laparoscopic revisional bariatric surgery as well as upper gastrointestinal surgery. The skills I picked up such as laparoscopic suturing and intra-corporal gastrointestinal anastomoses allowed me to have a broad based training in laparoscopic surgery. This built my confidence in handling LLR, especially in stressful situations when control of bleeding with sutures was required. I also had the opportunity to be involved in the management of many synchronous liver and colorectal resections, since the colorectal unit there was equally accomplished in advanced laparoscopic surgery.

The most important factors in embarking on safe laparoscopic liver surgery, in my experience, were the appreciation of liver anatomy from the caudal cranial view, learning laparoscopic haemostatic control and developing familiarity in using the laparoscopic ultrasound. In the initial learning process, many hours were spent assisting in laparoscopic surgeries and watching available videos to understand the various different approaches to major and minor resections in the caudal cranial perspective. While

this caudal cranial view afforded excellent visualization of the infra-hepatic tunnel for securing the short hepatic veins, the orientation of the resection plane can be confusing, and access to the major hepatic veins difficult. It is crucial to be able to control bleeding and the ability to laparoscopically suture quickly at awkward locations is a skill that should be practiced till proficient even before embarking on the 1<sup>st</sup> LLR without senior supervision. The use of the laparoscopic ultrasound was a difficult technique to learn but was indispensable to continuously check on resection line, vascular anatomy deep in the liver and also margin control especially for non-anatomical resections. While there are many known techniques of parenchymal transection with a variety of energy devices, it was important to learn and be familiar with one technique consistently before embarking on other methods. Although pure laparoscopy was generally preferred, before starting operations, a potential site for hybrid or hand port was routinely marked for conversion should there be situations of difficult bleeding control or failure to progress. I did not view conversion as a failure but a necessity especially when there are concerns about oncological clearance.

After returning to Singapore, I quickly began to develop a laparoscopic liver surgery program in my institution. Starting out, it was prudent to perform only simple wedge resections of anterolateral segments and LLS within the guidelines provided by the Louisville consensus statement for minor resections. This allowed me to train my team of junior surgeons and nursing staff under less technically demanding conditions, whilst avoiding the risk of significant patient morbidity during the early days of the program.

There was also cross collaboration with other colleagues from different institutions in Singapore, one of whom was a HPB surgeon (SYL) who did a laparoscopic and liver transplant fellowship in North America with Prof. Daniel Cherqui and subsequently a surgical oncology fellowship at Memorial Sloan Kettering Cancer Center (MSKCC). The first fellowship allowed him to not only learn first-hand from one of the pioneers of laparoscopic liver surgery but provided him an unique learning opportunity and interaction with a young attending at the same unit, who was Prof. Cherqui's fellow in Paris a few years prior. This provided valuable lessons and insights how one should cautiously and appropriately embark on a laparoscopic HPB practice. The availability of an experienced mentor in challenging cases was technically helpful and morally encouraging in and out of the operating room. It also provided a unique environment where he saw how

laparoscopic surgery can be safely integrated into living donor hepatectomies to decrease donor morbidity (25). The latter MSKCC fellowship was synergistic as it allowed him to experience another perspective—the role of MIS in HPB surgical oncology. Being a cancer center, in his opinion, MSKCC did not jump on the bandwagon of pursuing MIS surgery right from the start and its adoption of MIS was more calculated than other high volume tertiary centers because of the rightful concerns of MIS compromising the principles of surgical oncology (30,31). As Dr. Blake Cady once elegantly said: *“In the land of Surgical Oncology, biology is King; selection of case is Queen, and the technical details of surgical procedures are princes and princesses of the realm who frequently try to overthrow the powerful forces of the King and Queen, usually to no long-term avail, although with some temporary apparent victories.”* Nonetheless, because of potential benefits, culminating experience and convincing data, MIS and surgical oncology proves no longer to be mutually exclusive as long as patients are well selected and surgery performed by experienced teams (32).

In our initial experience, we worked together for major and complex hepatectomies operating with at least one other experienced laparoscopic liver surgeon (CYC). This was crucial in bringing different techniques learnt from our various training backgrounds and working to adapt these techniques to our local patients. In the Western institutions that we worked in, the majority of the resections were for colorectal liver metastases where the challenge was operating on post chemotherapy liver with the principle of parenchymal preservation. In addition, there were important lessons learnt in terms of multidisciplinary discussion and surgical approaches to combined colorectal and liver resections. In our local Asian population, we see a larger proportion of cases with HCC in cirrhotic livers (5). Besides chronic liver disease, they present additional challenges of portal hypertension with concurrent clinical coagulopathy and increased risk of bleeding. Furthermore they tolerate complications less readily and have a need for a larger future liver remnant. This has required us to adapt some techniques of liver mobilization and parenchymal transection in the setting of cirrhosis and portal hypertension. While our technique for parenchymal transection has been with hot “kelly-clysis” with a bipolar vessel sealing device, we have found the Calvitron Ultrasonic Surgical Aspirator (CUSA) (Tyco Healthcare, Mansfield, MA) as an important adjunct for careful dissection of lesions near major vascular pedicles. A roticulating energy device was also useful for non-anatomical

resections and lesions higher up in the dome of the liver together with a flexible tip endoscope.

In conclusion, a solid background in open liver surgery coupled with robust training in a high volume subspecialty laparoscopic centre provided a good foundation for starting laparoscopic liver surgery. Adaptation of techniques to the local context is crucial and inter-institutional collaboration allows synergistic development of skills to mount the learning curve for more complex laparoscopic hepatobiliary surgery. The challenge remains in selecting the appropriate patient for LLR and having better guidelines and scoring systems to anticipate the difficulty of resection would undoubtedly enable us to achieve this aim.

### Acknowledgements

None.

### Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

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**Cite this article as:** Chiuw AK, Lee SY, Chan CY, Tan SS. Learning curve in laparoscopic liver surgery: a fellow's perspective. *HepatoBiliary Surg Nutr* 2015;4(6):411-416. doi: 10.3978/j.issn.2304-3881.2015.06.07