Review Article

Laparoscopic liver resection: the current status and the future

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Abstract: Dramatic progresses had been made in the operation in the past 26 years. Procedure was extended to major liver resection, isolated resection of caudate lobe, living donor liver resection and associating liver partition with portal vein ligation for staged hepatectomy (ALPPS). Laparoscopic liver resection became a new group of HPB surgery and the international laparoscopic liver society was established in Paris followed by the first international congress of the society held in Paris in July 2017. This biannual congress would be top convention for surgeons specialized in laparoscopic liver surgery. The advantage of laparoscopic liver resection had been recognized by patients and surgeons and is gradually replacing conventional open liver resection in some experienced institutes worldwide. Most procedures, such as laparoscopic local resection and left lateral segmentectomy, could be routinely performed, but some procedures including laparoscopic hemihepatectomy still need to be further evaluated. For now, the establishment of a training system for laparoscopic liver surgeons became the most important issue for the popularization of laparoscopic liver resection.

Keywords: Laparoscopic; liver resection; hepatectomy; hepatocellular carcinoma (HCC); hepatolithiasis; liver cirrhosis

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Introduction

In 1991, the first laparoscopic liver resection (LLR) was reported by Reich *et al.* (1). Three years later, Zhou Weiping *et al.* reported the first case of laparoscopic liver resection in China in the Chinese journal of hepatobiliary surgery. Dramatic progresses had been made in the operation in the past 26 years. Procedure was extended to major liver resection, isolated resection of caudate lobe, living donor liver resection and associating liver partition with portal vein ligation for staged hepatectomy (ALPPS). Milestones for laparoscopic liver resection were the convention of international expert consensus of laparoscopic liver resection in Louisville in 2008 and the establishment of international laparoscopic liver society in Paris in 2016. The first and second international consensus conferences on laparoscopic liver resection were held in 2008 and 2014 and consensuses were released after congresses which guided clinical practice of laparoscopic liver resection worldwide (2,3). The first international congress of the international laparoscopic liver society was held in Paris in July 2017 and will be held biannually as the top meeting for surgeons specialized in laparoscopic liver surgery. The advantage of laparoscopic liver resection had been recognized by patients and surgeons and is gradually replacing conventional open liver resection in some experienced institutes worldwide. In the first 10 years of twenty-first century, laparoscopic liver resection was in the course of technique innovation and procedure exploration. In the recent years, surgeons focus more on the assessment of the value of laparoscopic liver resection over conventional open liver resection, furthermore, it is essential to evaluate the feasibility and safety of laparoscopic liver resection performed routinely in ordinary hospitals other than in these experienced institutes. The systematic training of laparoscopic liver surgeons became the most important issue in the popularization of

laparoscopic liver resection. In our country, laparoscopic liver resection started a little later than European countries, but we kept step with the world in the technique innovation, procedure exploration and instruments development by efforts of Chinese liver surgeons.

Surgical indications

With accumulation of experience, innovation of techniques and development of instruments, the indication of laparoscopic liver resection has expanded and is almost similar to the open liver resection (4), but some procedures are still not suit for the majority of institutes and surgeons.

Generally, superficial lesions located in segment II, III, IV, V, VI are indicated for the laparoscopic liver resection. Local resection and left lateral segmentectomy are the major procedures. Laparoscopic hemihepatectomies were performed in some institutes for large liver tumors or hepatolithiasis. In some experienced institutes, laparoscopic liver resection was also performed for tumors located in caudate lobe, segment VII and segment VIII (5-11). Liver malignancies, including primary liver cancer, secondary liver cancer and other rare liver malignancies, were indications of laparoscopic liver resection. In a global systematic review in 2016 (4) revealed that 6,190 cases (65%) were performed for malignancy and 3,337 cases (35%) for benign indications. Many patients with HCC combined with liver cirrhosis, which makes procedures more difficult and dangerous with increased risks of bleeding and liver failure. Laparoscopic living donor liver resection is still in the exploratory stage. On the 2nd international expert consensus conferences on laparoscopic liver resection in Morioka (Japan), senior liver surgeons failed to reach a consensus to carry out laparoscopic liver donor liver resection because of the concern on the absolutely safety of donors, however, this procedure still had a great potential to be used worldwide because of its minimally surgical invasion for donors.

In the past 26 years, contradictions of laparoscopic liver resection were conquered one by one by efforts of laparoscopic liver surgeons, the development of equipments for liver resection and innovations in surgical procedures. Recently, following the discovery of the associating liver partition and portal vein ligation for staged hepatectomy (ALPPS) (12), some patients with estimated future liver remnant less than 30% could be treated with the laparoscopic two-stage liver resection instead of liver transplantation (13-15).

Equipments and techniques for laparoscopic liver resection

Instruments including harmonic scalpel, ultrasonic dissector, cavitron ultrasonic surgical aspirator (CUSA), laparoscopic Peng's multifunctional operative surgical dissector (LPMOD), LigaSure, endoscopic linear stapler and microwave coagulating scalpel were used in laparoscopic liver resection (16,17). Most these instruments have functions of cutting and hemostasis by energy and some of them have the function of dissection. The LPMOD was developed by ourselves have multifunctions of dissection, cutting, aspiration and coagulation. It showed advantages in safety and efficiency in transecting liver parenchyma and dissecting small vessels inside liver parenchyma (18). Each instrument has its own merits and a group of surgeons familiar with it. It is difficult to conclude which one superior to the other and each of them would be a good one if used by surgeons familiar with it.

Laparoscopic ultrasonography plays an important role in laparoscopic hepatectomy, especially in locating liver lesions and major vessels deep in the liver parenchyma. Differ from CT, MR or 3-dimension print, it could be repeated frequently in the operation giving real-time images to assess the resectability in laparoscope, accurately locate the tumor and major vessels and help achieving a proper transection plane in patients with liver malignancies (19,20). The loss of hand-touch could be made up by the ultrasound and facilitate laparoscopic liver resections.

Robot-assisted surgeries have been applied to the hepatectomy (21-23) providing stereo visions and meticulous manoeuvre. The value of the equipment in liver surgery is still controversial. The mechanical arms and wrists of robotic operation system enable precise and accurate resection of liver lesions, but it might be inefficient to manage large liver lesions. Furthermore, the high cost of the robotic surgery hinders its application. In short, the value of robotic surgery in laparoscopic liver resection needs to be further evaluated.

The techniques for laparoscopic liver resection are diverse and mostly depend on the instruments that surgeons selected. There is no great technique difference between surgeons using the same instrument. Most surgeons use different instrument in different circumstance or perform laparoscopic liver resection by combined use of diverse instruments, such as ultrasonic dissector for superficial liver parenchyma and linear stapler for liver parenchyma with major vessels inside it.

Laparoscopic hepatic inflow control

Normally, there are some methods, the Pringle maneuver and the selective hepatic inflow occlusion, were frequently used for hepatic inflow control. Pringle maneuver is the traditional method and is most frequently used in the early stage of laparoscopic liver resections and laparoscopic selective hepatic inflow occlusion emerged almost simultaneously with the laparoscopic major liver resection in our institute which avoids the ischemia-reperfusion injury and hemodynamic change. We developed laparoscopic selective inflow occlusion in early 2005 to control intraoperative bleeding and it is performed routinely in anatomical major liver resections (24). Pringle maneuver is still ideal method to help managing massive bleeding in laparoscopic liver resections. Hepatic inflow control is not a routine procedure in laparoscopic liver resection, but pre-placement of hepatic inflow occlusion instruments in abdominal cavity could be a protective measure for these initiates in laparoscopic liver surgery.

Procedures of laparoscopic liver resection

Procedures of laparoscopic liver resection were divided into non-anatomical liver resection and anatomical liver resection. Non-anatomical liver resection includes wedge resection, local resection and lesion enucleation. Anatomical liver resection includes left lateral sectionectomy, left hemihepatectomy, right posterior sectionectomy, right hemihepatectomy and combined caudate lobectomy. The first laparoscopic liver resection was local resection which is still the major procedure of laparoscopic liver resection now. Left lateral segmentectomy which was reported in 1990s is the major procedure of laparoscopic anatomical liver resection. It was recommended as a routine liver surgery by the 1st international expert consensus on laparoscopic liver resection in 2008 (2). Procedures including isolated caudate lobectomy, trisegmentectomy and middle hepatic lobectomy (segments 4, 5, and 8) are rarely performed even in experienced institute for the technique difficult and the risk of massive bleeding (25,26). For the tumor located in segment VII and VIII, normal laparoscopic instruments are difficult to reach. High risks of massive bleeding and positive tumor margin hinder the development of these procedures. Frankly, I don't recommend laparoscopic surgery for lesions in the area for most institutes. However, it is not a contra-indication of laparoscopic liver resection. It could be performed by experienced surgeons or with special instruments such as intercostal trocars (27) or transthoracic laparoscopic devices (28).

Laparoscopy was applied in donor liver resection since Cherqui *et al.* (29) reported the first laparoscopic living donor left lateral sectionectomy in 2002. Laparoscopic living donor liver resection is still in the exploratory stage and was hindered by these forementioned controversies, but it still has a potential to be used as a routine procedure to achieve donor liver in most liver centers.

ALPPS was a method to attain rapid growth of future liver remnant. However, the postoperative severe adhesion after the first-stage operation of liver splitting increases the surgical difficulty of the second-stage operation. Laparoscopy as a minimal invasive procedure was reported to reduce adhesion (8) and laparoscopic ALPPS was reported (30,31) immediately after it was reported. However, the occurrence rate of bile leakage after the first-stage operation was high (32). In our institute, we developed the technique of laparoscopic round-the-liver ligation to replace liver splitting in the first-stage operation to avoid biliary leakage from the split liver plane. As our current experience, completely laparoscopic ALPPS using round-the-liver ligation could achieve an equal effect as liver partition and avoid bile leakage after the first-stage operation (14,18).

Outcomes of laparoscopic liver resection

Nguyen *et al.* (33) had reviewed 2,806 case worldwide and found that the overall complication is 10.5%. The most common liver-related complication was bile leakage (1.5%) and the most common general complication was pleural effusion (0.5%). In our institute, the postoperative bleeding rate was 0.4% and bile leakage rate was 0.8% (18). Meticulous dissection of intrahepatic vessels and bile ducts is the point to address these liver-related complications. Conversion rate was great different in reports from different institute worldwide. Difference of inclusion criteria in these institutes might be able to explain it. In my opinion, conversion is not a failure of operation, but a change of entry for the operation. The point is that we should convert decidedly before a severe consequence occurred.

The majority of laparoscopic liver resections were indicated for liver malignancies (34,35). The choice of the proper oncologic plane is important for the survival time. It could be more difficult to get a proper resection plane in laparoscopic liver resection compared with open liver resection because of the loss of touch. The long-term effect

is the major controversy on laparoscopic liver resection for liver malignancies and many retrospective or case-matched studies had been carried out (36-42). According to current experience, there is no difference of survival time between laparoscopic liver resection and open liver resection, but the final conclusion should base on data from multi-center and randomized case-controlled clinical trials. Unfortunately, there is little result of randomized clinical trials on laparoscopic liver resection over open liver resection for liver malignancies available for the long-term outcome analysis. In 2015, a multi-center and case-matched study about laparoscopic liver resection for colorectal liver metastasis (43), in which data was collected from 32 centers in France, found that short-term results such as postoperative hospital stay and complication rate were better in laparoscopic group compared with open group and there was no significant difference of 3 and 5 years survival rates between the two groups. According to the systematic review from Ciria *et al.* (4), adequate free margins were obtained in 82% to 100%.

Liver cirrhosis is always accompanied with hepatocellular carcinoma and is the great challenge to laparoscopic liver surgeons because of the high volume of intra-operative bleeding, the high occurrence rate of unmanageable bleeding and the high conversion rate as well. The major indication for liver resection is hepatocellular carcinoma which always accompany with liver cirrhosis, so the safety of laparoscopic liver resection for cirrhotic livers must be conquered in the development of laparoscopic liver surgery. Cherqui *et al.* (44) reported the laparoscopic liver resection for hepatocellular carcinoma with liver cirrhosis (chronic liver disease) in 2006. In the 27 patients, 5 patients (18.5%) converted to laparotomy for moderate hemorrhage and the mortality and morbidity rates were 0% and 33%. He concluded that laparoscopic liver resection for HCC in selected patients is a safe procedure with very good midterm results. Even though the high risk of bleeding in cirrhotic liver, laparoscopic liver resection is still an alternative for patients with hepatocellular carcinoma and liver cirrhosis (45). For now, all the instruments for laparoscopic liver resection were used for cirrhotic liver and there is no instrument was proven to be superior to the others for the laparoscopic transection of a cirrhotic liver. Normally, the selection rules of instruments are unchanged in transecting a cirrhotic liver, but the transection could be significantly slowed when using the ultrasonic dissector or CUSA. The LPMOD might keep the efficiency in the transection of cirrhotic liver. In general, laparoscopic liver resection could be performed on patients with liver cirrhosis and liver function of Child A to B, but conversion should be made if any sign of unmanageable bleeding occurred.

The learning curve of laparoscopic liver resection

As a high-risk operation, it is essential to train surgeons who specialized both in hepatobiliary surgery and laparoscopic surgery to master it. The second international expert consensus conference of laparoscopic liver resection (3) concluded the necessity to establish a formal structure of education for those who are interested in the laparoscopic liver resection. The acquisition of basic technical skills could acquire through the practice in animal model, but further clinical training need to be cautious. In the initial clinical experience, local resections of small tumors located in the anterolateral segments should be the first choice. The training of anatomical resections could start after familiar with the laparoscopic left lateral segmentectomy. Fortunately, a systematic and learning curve-based training course which combined with simulated training, animal-based liver resection and expert-guided clinical liver resection will be established by experts of liver surgery in China in the near future.

Laparoscopic liver resection in China

The development of laparoscopic liver resection is synchronous with the international level. We collected and analyzed reports from Chinese institutes on PubMed. Total of 4,459 cases were reported by institutes in China. Pure laparoscopic procedures occupied 88.5% of reported cases, hand-assisted and laparoscopic assisted procedures were 5.3% and robotic-assisted was 6.1%. Left lateral segmentectomy (23.9%) and local resection (21.3%) were major procedures of laparoscopic liver resection, and hemi-hepatectomy occupied 15.6% of these reported cases. Sixty percent of the cases were indicated for malignant liver lesions, and the 39% were indicated for benign lesions. The majority of these malignant cases were hepatocellular carcinoma (HCC, 77%). The other malignancies included liver metastasis from colorectal cancer (16%), cholangiocarcinoma (4%), and so on. Complication rate was 13.2% in China. The major complication was bile leakage (2.3%). The mortality rate was 0.06% including two patients complicated with liver failures. Reported conversion rates were ranged from 0% to 12.3% in China,

varying mostly depending on patient selection, types of procedure and surgeons' experience. The conversion rate of completely laparoscopic liver resection in reported literatures in China was 5%. The most common reason was bleeding (45.9%). Other reasons including adhesion, difficulty in locating tumors, macroscopic positive margin, and so on.

Future

The next challenge of laparoscopic liver resection is the standardization of these procedures and the systematic training of young surgeons. Procedures with high complication rate or conversion rate should be further improved by developing new techniques and inventing new instruments. The establishment of training system is mandatory in the near future for the purpose of popularizing this operation. In addition, with the development of computer technology, optical science, machinery manufacturing, materials science, etc., real-time and three-dimensional image reconstruction, flexible laparoscopic instruments, tactile feedback laparoscopic system are expected to be used in laparoscopic liver resection to improve the safety and efficacy of this operation. In the near future, we should put efforts on the training of laparoscopic liver surgeons

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Footnote

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