World Journal of Gastrointestinal Oncology

Online Submissions: http://www.wjgnet.com/esps/
wjgo@wjgnet.com
doi:10.4251/wjgo.v4.i8.187

World J Gastrointest Oncol 2012 August 15; 4(8): 187-192
ISSN 1948-5204 (online)

EDITORIAL

Laparoscopic liver resection: Current role and limitations

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Received: December 13, 2011 Revised: July 31, 2012
Accepted: August 6, 2012
Published online: August 15, 2012

Abstract

Laparoscopic liver resection (LLR) for the treatment of benign and malignant liver lesions is often performed at specialized centers. Technological advances, such as laparoscopic ultrasonography and electrosurgical tools, have afforded surgeons simultaneous improvements in surgical technique. The utilization of minimally invasive techniques for liver resection has been reported to reduce operative time, decrease blood loss, and shorten length of hospital stay with equivalent postoperative mortality and morbidity rates compared to open liver resection (OLR). Non-anatomic liver resection and left lateral sectionectomy are now routinely performed laparoscopically at many institutions. Furthermore, major hepatic resections are performed by pure laparoscopy, hand-assisted technique, and the hybrid method. In addition, robotic surgery and single port surgery are revealing early promising results. The consensus recommendation for the treatment of benign liver disease and malignant lesions remains unchanged when considering a laparoscopic approach, except when comorbidities and anatomic limitations of the liver lesion preclude this technique. Disease free and survival rates after LLR for hepatocellular carcinoma and metastatic colon cancer correspond to OLR. Patient selection is a significant factor for these favorable outcomes. The limitations include LLR of superior and posterior liver lesions; however, adjustments in technique may now consider a laparoscopic approach as a viable option. As growing data continue to reveal the feasibility and efficacy of laparoscopic liver surgery, this skill is increasingly being adopted by hepatobiliary surgeons. Although the full scope of laparoscopic liver surgery remains infrequently used by many general surgeons, this technique will become a standard in the treatment of liver diseases as studies continue to show favorable outcomes.

Key words: Laparoscopic liver resection; Laparoscopic hepatectomy; Minimally invasive liver surgery; Hand-assisted technique; Hybrid technique

Peer reviewers: Satoru Takayama, MD, Department of Gastroenterological Surgery, Nagoya City University, 1 Kawasumi, Mizuho-cho, Mizuho-ku, Nagoya 467-8601, Japan; Simon Ng, Professor, Division of Colorectal Surgery, Department of Surgery, University of Hong Kong; Department of Surgery, Prince of Wales Hospital, Shatin, Room 64045, 4/F, Clinical Sciences Building, Hong Kong, China

Mostaedi R, Milosevic Z, Han HS, Khatri VP. Laparoscopic liver resection: Current role and limitations. *World J Gastrointest Oncol* 2012; 4(8): 187-192 Available from: URL: http://www.wjgnet.com/1948-5204/full/v4/i8/187.htm DOI: http://dx.doi.org/10.4251/wjgo.v4.i8.187

INTRODUCTION

The advent of laparoscopic cholecystectomy demonstrated an associated decrease in postoperative morbidity, decreased blood loss, and reduced length of hospital

stay, which ushered the transition of minimally invasive techniques for a wide range of surgical diseases. Just over the last two decades, numerous case series indicate that laparoscopic liver surgery has become a viable option for benign liver disease, primary malignancy, and metastatic liver disease. Recent data reveal that specialized centers have successfully performed laparoscopic major hepatectomies with favorable outcomes when compared to open hepatectomies[1-4]. Peripherally located liver lesions, such as the left lateral segments, are treated by surgeons with minimally invasive expertise as a standard of care[5]. Hepatobiliary surgeons are embracing the technological advances in laparoscopy-necessary skills for their surgical practice[3,5]. The favorable outcomes initially observed in laparoscopic liver wedge resections and minor hepatectomies to the current pure laparoscopic major hepatectomies and laparoscopic liver resections (LLRs) of the posterior segments have continue to redefine the surgical treatment of benign and malignant liver diseases[5-9].

Since the first reported LLR performed in 1992, over 3000 liver resections have been performed[10]. In 2008, a consensus of experts in both open and laparoscopic liver surgery established the Louisville Statement-a guideline summary on the rapidly evolving adoption of minimally invasive liver resection[5]. Recent case series are exploring robotic-assisted LLR and video-assisted thoracoscopic surgery-hepatectomy (VATS-H) as additional options for hepatic lesions[11-15]. This review discusses the various types of minimally invasive hepatectomies, indications, limitations and complications, and the future of LLR.

TYPES OF LLR

The various types of minimally invasive techniques have become more refined for both minor and major hepatectomies. The Louisville Statement has categorized laparoscopic techniques for liver resection into three groups: (1) Pure laparoscopy; (2) Hand-assisted; and (3) Hybrid technique[5].

Pure laparoscopy is defined as a total laparoscopic procedure, which excludes hand-assisted techniques, conversions to open procedures, and the adjunctive use of a separate celiotomy incision to assist in the dissection and complete transection of the liver. Pure LLR is generally feasible for wedge biopsies and resection of lesions in the peripheral and anterior liver segments[5,8,9]. At specialized centers, pure laparoscopy has been utilized for bisegmentectomies, trisegementectomies, and other major hepatectomies[1,3,4,7,9].

The hand-assisted technique affords the surgeon a greater ease at mobilizing the liver, digital manipulation, and countertraction. This allows surgeons with minimal experience in LLR the additional benefit of also addressing operative bleeding. As for skilled laparoscopic hepatobiliary surgeon, this provides them the ability to approach the more difficultly located liver lesions, especially the posterior and superior segments, and major hepatectomies[3,6,16].

Dagher *et al*[7] performed a multi-institutional review on laparoscopic major hepatectomy from a prospective database. The procedure was planned as either a pure laparoscopic (n = 91, 43.3%) or hand-assisted laparoscopic (n = 119, 56.7%) liver resection. They showed that there was a statistical difference in operative time between the two groups (299.9 ± 112.3 min *vs* 230.2 ± 86.4 min, P < 0.0001). The combined perioperative mortality (n = 2, 1.0%), liver-related complications (n = 17, 8.1%), and surgical-related complications (n = 29, 13.8%) were low, and both groups had similar conversion rates. The study indicates that both pure laparoscopic and hand-assisted laparoscopic major hepatectomies are feasible options with low morbidity and mortality at specialized centers.

The hybrid technique for minimally invasive liver resection is defined as a laparoscopic-assisted open liver resection (OLR). The procedure is initially performed either by the pure laparoscopic or hand-assisted technique, and the completion hepatectomy, which includes the hilar dissection and parenchymal transection, is performed through a separate celiotomy incision. The hybrid technique may provide the first step for both general and hepatobiliary surgeons at attempting laparoscopic liver surgery. In a small series, the hybrid technique had similar operative times, but reduced blood loss and length of hospital stay compared to the OLRs[17].

Minimally invasive techniques have also been utilized by transplant liver surgeons. Baker *et al*[1] retrospectively compared patients who underwent laparoscopic-assisted donor right hepatectomy (n = 33) to open donor right hepatectomy (n = 33). Both groups had similar rates of live donor complications based on the Clavien classification: five (15.2%) grade Ⅰ, two (6.1%) grade Ⅱ, and no grade Ⅲ or Ⅳ complications. The hybrid technique group had decreased blood loss, decreased operative time, and quicker resolution of postoperative pain. The incorporation of minimally invasive techniques in live donor hepatectomy will likely show similar benefits observed in laparoscopic live donor nephrectomy.

ADVANCES IN LAPAROSCOPIC DEVICES

In addition to laparoscopic ultrasonography, evolving electrosurgical devices for hepatic transection have lessened the amount of the blood loss and improved intraoperative visualization. Bipolar cautery forceps and ultrasonic coagulating shears are widely used and provide critical parenchymal dissection. Furthermore, saline-linked cautery is described to produce an almost bloodless parenchymal transection[3]. These devices aid in the identification of hepatic and portal vasculature prior to stapling of the main vessels.

Gaining control of the hepatoduodenal pedicle has been vital technique in performing complex liver procedures. Similarly in laparoscopic liver surgery, the primary surgeon will decide whether to dissect the vascular pedicle to allow for the Pringle maneuver, especially in cirrhotic patients. The lesser omentum is incised, and an

umbilical tape is passed around the pedicle for control when necessary.

INDICATIONS AND CONTRAINDICATIONS

Diagnostic laparoscopy and ultrasonography are considered to be standard practice in the treatment of malignant liver diseases, especially to exclude patients with carcinomatosis and to appreciate oncologic margins[18,19]. The indications for LLR should follow the same guideline for OLR, but limited to patients amenable to minimally invasive surgery. Overall, the consensus recommends that patients with solitary lesions, less than 5 cm, and within peripheral segments may be amenable to LLR, and major hepatectomies should be reserved for specialized liver centers[5].

In addition to the contraindications for OLR, patients with tumor extension to the hilum, central hepatic veins or inferior vena cava, extensive intra-abdominal adhesions, contraindication to pneumoperitoneum, and the need for complex vascular or hepatobiliary reconstruction or extensive lymphadenectomy should generally be approached as a hybrid or an open procedure.

BENIGN LIVER DISEASE

There is a wide range of benign hepatic lesions that are treated by liver resection, such as symptomatic hemangiomas, focal nodular hyperplasia, hepatic adenomas, symptomatic simple cysts, complex cysts, and symptomatic type I polycystic liver disease. Most benign liver lesions are asymptomatic and monitored on surveillance imaging. These lesions are routinely followed; however there is a concern for an increased prevalence of liver resection, specifically attributing to the addition of minimally invasive liver resection. Currently, there is no evidence to expand the criteria for the treatment of benign liver diseases with the use of minimally invasive techniques[20].

Laparoscopic major hepatectomies have been shown to be feasible at specialized centers[4,21]. The series by Tu *et al*[4] compared laparoscopic (n = 28) to open left hepatectomy (n = 33) for the treatment of hepatolithiasis. Complication rates were similar (14.2% *vs* 15.2%), and there were no perioperative mortality. Laparoscopy should be an option offered to patients, especially for wedge resections and minor hepatectomies, whereas major hepatectomies should be reserved for minimally invasive hepatobiliary surgeons.

MALIGNANT LIVER DISEASES

Multiple clinical series have shown good oncologic outcomes in the treatment of both hepatocellular carcinoma (HCC) and colorectal cancer liver metastases with the use of minimally invasive techniques[9,22-24]. These studies show that small peripheral lesions treated with laparoscopic resection are consistent with the oncologic outcomes observed in OLR. Furthermore, specialized centers are showing good oncologic outcomes for the more difficultly located lesions.

Metastatic colorectal cancer

Multiple studies have shown good 5-year survival rates for the OLR for the treatment of colorectal cancer liver metastases[2,25-27]. The 5-year survival in these studies ranges from 44% to 58%, and the 5-year disease free survival ranges from 27% to 30%. The introduction of laparoscopic techniques for liver resection has raised questions on the merits of achieving equivalent oncologic outcomes. There are no randomized controlled trials comparing open *vs* LLR for metastatic colorectal cancer, but several case series have shown equivalent long-term survival outcomes in selected patients[2,23,28]. The 5-year survival ranges from 50% to 64%, and the 5-year disease free survival ranges from 35% to 43% in selected patients undergoing LLR.

The role of minimally invasive liver resection has expanded to the treatment of synchronous disease, such as primary colon cancer with liver metastases[29,30]. These small series show that the combined procedure is technically feasible. These are promising early results, and more studies are needed to be done to assess the long-term outcomes.

HCC

The 5-year survival rates can reach up to 50% in selected patients with resectable HCC[24,31,32]. Patients with early HCC may be candidates for LLR without the surgical-related morbidity of open liver surgery, and to achieve equivalent oncologic outcomes[22,24]. Tranchart *et al*[24] compared open to LLR for the treatment of HCC, and the oncologic outcomes were similar at 1-year (81.8% *vs* 93.1%), 3-year (73% *vs* 74.4%), and 5-year (47.4% *vs* 59.5%), respectively. The liver-related morbidity (28.5% *vs* 11.9%) and surgical-related morbidity (11.9% *vs* 9.5%) were better in the laparoscopic group, and disease recurrence (12 patients *vs* 10 patients) was equivalent for both groups.

The Milan Criteria was adopted by the United Network for Organ Sharing for orthotopic liver transplantation in patients with cirrhosis and early stage HCC. However, there are numerous patients who meet the Milan Criteria but definitive liver transplantation is delayed due to the limited availability of liver donors. Patients with solitary or multiple peripheral HCC can be treated with liver resection during the interim with good outcomes[33]. Minimally invasive liver resection may offer the additional means to minimize surgical-related morbidity associated to an open resection, which should decrease potential operative complications and operative time with eventual liver transplantation. LLR for HCC should be considered in selected patients who are on the transplant waiting list.

LIMITATIONS

The current literature reveals that laparoscopic major

hepatectomies are performed at specialized centers by hepatobiliary surgeons skilled in minimally invasive techniques. A priority for the safe dissemination of the laparoscopic liver surgery has been addressed, yet there is no uniform consensus on the criteria for certification and credentialing[5]. However, the recommendation for surgeons with limited experience in complex laparoscopic liver surgery should begin with minor hepatectomies, such as the left lateral sectionectomy or minor non-anatomic hepatectomy[5,7], and transition to major hepatectomies with the hybrid approach[17].

A risk-adjusted Cumulative Sum analysis determined that the learning curve for LLR is 60 cases[34]. LLRs during three consecutive periods were compared to open resections, and significant improvements were seen in conversion rates (15.5%, 10.3% and 3.4%, $P < 0.005$), operative time (210, 180 and 150 min, $P < 0.05$), and operative blood loss (300, 200 and 200 mL, $P < 0.05$)[34].

The results of LLR are promising, and presently show favorable outcomes in postoperative morbidity and mortality[35]. The role of LLR for difficultly located lesions, specifically in the posterior and centrally located regions, is becoming a viable option for many minimally invasive hepatobiliary surgeons[9,16,36]. These early single institution studies indicate that laparoscopic techniques are feasible with equivalent perioperative complication rates. One of the author, Han HS from Seoul National University Bundang Hospital, has been applying LLR for tumor located in posterosuperior segment. As laparoscopic approach for the lesion located in posterosuperior segment is technically difficult with the possibility of significant bleeding during operation, it is recommended to be performed by very experienced surgeons.

The retrospective analysis by Cho *et al*[36] compared laparoscopic ($n = 42$) to open ($n = 40$) liver resection for lesions located on the right side of the liver. Their results did not show a significant difference in the rate of complications (27.5% *vs* 28.6%), operative time, estimated blood loss, or number of operative blood transfusions. Yoon *et al*[9] compared patients with lesions located in the anterolateral segments (AL group, $n = 44$) to posterosuperior segments (PS group, $n = 25$) undergoing LLR for HCC. The PS group had a longer operative time ($P = 0.001$), longer length of hospital stay ($P = 0.039$), higher rate of open conversion ($P = 0.054$), and greater estimated blood loss ($P = 0.068$). There were no statistical difference in postoperative complications (18.2% *vs* 28.0%), recurrence rate (34.0% *vs* 24.0%), 3-year overall survival (84.6% *vs* 100.0%), or disease-free survival (58.5% *vs* 63.4%) between the two groups.

These case series on LLR for lesions in the centrally located, superior and posterior segments are promising. However, further review needs to be done to confirm its feasibility and appropriateness in selected patients.

COMPLICATIONS

Safe laparoscopic principles have long been established, and the philosophy of open conversion should not be considered a complication, but as part of the planned procedure for difficult dissections, uncontrolled bleeding, and for the safety of the patient. However, the failure to convert and the associated consequences should still remain to be considered a complication. Expert understanding of liver anatomy and physiology, and extended experience in laparoscopic liver surgery is necessary for low complication rates similar to OLRs.

The meta-analysis of laparoscopic hepatectomies by Nguyen *et al*[35] found that the overall morbidity rate was 10.5% (range 0% to 50%), and overall mortality rate was 0.3% (range 0% to 10%) in 2804 patients. The most common postoperative complication was a bile leak (1.5%) followed by transient hepatic insufficiency (1.0%). The most common general- and surgical-related complications were pleural effusions, incisional bleeding and wound infections-each less than 1%. In several large series, the overall morbidity rate ranges from 22% to 45%, and the overall mortality rate ranges from 3.1 to 4.9% and decrease to 1.3% in the last decade reported by Jarnagin *et al*[37] for OLRs[37-39]. The overall morbidity and mortality rates for LLR are favorable compared to these large series on OLR.

FUTURE

Early results for the utilization of single port laparoscopy have shown to be feasible with minimal rates of complication similar to multiport laparoscopic liver surgery[40-43]. Patient selection was general limited to anterolateral segments and tumors < 3 cm[40,41]. In a recent case series, single port laparoscopic major hepatectomy was performed in 2 patients with HCC[43]. There were no reported complications and no cancer recurrence. These early experiences reported longer operative time and limitations due to instrumentation length and triangulation.

There are case series on patients undergoing robotic-assisted LLR and VATS-H[11-15]. These novel techniques have been shown to be successful in both minor and major hepatectomies, and for liver tumors located in difficult anatomic locations.

Giulianotti *et al*[13] reported no deaths and the overall complication rate was 21.4% in 70 patients undergoing robotic-assisted laparoscopic liver surgery. Ji *et al*[14] reviewed 13 consecutive patients, and there were no reported deaths and the overall complication rate of 7.8%. Chan *et al*[12] also reported similar results performed in 27 patients with no reported deaths and morbidity of 7.4%.

Berber *et al*[11] reported a comparative analysis on robotic ($n = 9$) and laparoscopic ($n = 23$) liver resection. Operative time (234 ± 17 min *vs* 259 ± 28 min), blood loss (136 ± 61 mL *vs* 155 ± 54 mL), negative tumor margins and complication rates (11% *vs* 17%) were similar for both groups.

Murakami *et al*[15] reported a small series of 5 patients undergoing VATS-H for subdiaphragmatic liver tumors. The procedure was performed with both thoracoscopic

and laparoscopic ports, and intraoperative thoracoscopic ultrasound was used to localize the liver tumor over the diaphragm. The blood median blood loss was 43 g (0-200 g) and median total operating time was 137 min (95-185 min). There were no perioperative deaths or complications such as re-exploration, postoperative bleeding, biliary fistula, hydrothorax, or hepatic failure. The patients on follow-up did not show any evidence of recurrent disease. The VATS-H may thus provide another surgical option for the difficultly located liver tumors.

CONCLUSION

The associated risks for OLR have been well documented[37-39]. Belghiti *et al*[38] reported an overall in-hospital mortality rate of 4.4% (9.5% with an underlying liver disease and 1% without an underlying liver disease). The large meta-analysis of LLR by Nguyen *et al*[35] reported a total mortality rate of 0.3% and complication rate of 10.5%

Koffron *et al*[3] reported in a large, single-center experience of 300 LLRs which were compared to 100 contemporaneous, cohort-matched OLRs. The LLR group compared favorably to the OLR in operative times, blood loss, and length of hospital stay. The overall complications rate was less in the LLR group (9.3% *vs* 22%).

As more hepatobiliary surgeons are adopting laparoscopic liver surgery into their practice, guidelines and consensus statements are now being established to provide a standard approach to the treatment of benign and malignant liver diseases with minimally invasive techniques. LLR of complex lesions and difficultly located lesions has shown to be feasible in case series, but should be reserved for minimally invasive hepatobiliary surgeons at specialized centers. Anterior and peripheral hepatic lesions should be evaluated for a minimally invasive approach, and left lateral sectionectomy is considered to be a standard surgical treatment option. Perioperative complication rates and long-term oncologic outcomes appear to be favorable, and continue to be a viable surgical option at specialized centers. Robotic-assisted laparoscopic hepatectomies and VATS-H show promising early results in the few small case series, but undoubtedly will become another option in selected patients.

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