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REVIEW

The Role of Laparoscopic Surgery in the Management of Hepatocellular Carcinoma

Justin A. Steggerda[1,2] · Steven A. Wisel[1,2] · Nicholas N. Nissen[1,2] · Georgios Voidonikolas[1,2] · Kambiz Kosari[1,2]

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Abstract

Purpose of Review Hepatocellular carcinoma (HCC) is the most common primary liver tumor and 6th most common cancer overall. This article reviews the role of laparoscopy in the multi-disciplinary management of HCC.

Recent Findings Laparoscopic surgery involves multiple approaches for diagnosis and treatment of HCC, including intraoperative ultrasound and biopsy, as well as ablative strategies for tumors in difficult locations. In comparison to catheter-based therapies, hepatic resection offers similar survival with the benefit of direct visualization to identify additional tumors. Laparoscopic liver resections further show similar oncologic outcomes with reduced hospital length of stay and reduced morbidity compared to open approaches and may even be used to treat large tumors.

Summary Laparoscopic surgery may be involved in the diagnosis, treatment, and resection of HCC. Laparoscopic hepatic resections are safe with equivalent oncologic outcomes and may offer advantages over catheter-based therapies in selected patients. Advances in robotic surgery have served to expand the potential for minimally invasive approaches in the surgical treatment of HCC.

Keywords Minimally invasive surgery · Hepatic resection · Liver ablation · Liver tumors

Abbreviations

HCC	Hepatocellular carcinoma
HCV	Hepatitis C virus
HR	Hepatic resection
LT	Liver transplantation
MIS	Minimally invasive surgery
MASLD	Metabolic dysfunction–associated steatotic liver disease
MASH	Metabolic dysfunction–associated steatohepatitis

✉ Justin A. Steggerda
justin.steggerda@cshs.org

Steven A. Wisel
steven.wisel@cshs.org

Nicholas N. Nissen
nicholas.nissen@cshs.org

Georgios Voidonikolas
georgios.voidonikolas@cshs.org

Kambiz Kosari
kambiz.kosari@cshs.org

1 Division of Abdominal Transplant and Hepatobiliary Surgery, Department of Surgery, Cedars Sinai Medical Center, Los Angeles, CA, USA

2 Comprehensive Transplant Center, Cedars Sinai Medical Center, 8900 Beverly Blvd, Second Floor, Los Angeles, CA 90048, USA

Introduction

Hepatocellular carcinoma (HCC) is the 6th most common cause of cancer and 4th most common cause of cancer-related mortality globally (2018 WHO statistics). Worldwide, the highest incidence of HCC is found in low- and middle-resource countries such as those in Eastern and Southeastern Asia and Africa [1–3]. Globally, etiologies for HCC are similarly broad, with chronic hepatitis B virus (HBV) and aflatoxin B1 accounting for much of the disease in developing regions such as China and India, while hepatitis C virus (HCV) and metabolic dysfunction–associated steatotic liver disease (MASLD) and metabolic dysfunction–associated steatohepatitis (MASH) account for the majority of cases in Western countries [4–7].

Multiple staging systems have been developed for HCC. The most commonly used Barcelona Clinic Liver Cancer (BCLC) system is based upon tumor burden, patient performance status, and liver dysfunction and has the ability to predict prognosis to guide therapeutic decision-making for patients with HCC [8]. Surgical options, such as hepatic resection (HR) or liver transplant (LT), yield the best outcomes for patients with HCC with 5-year survival rates of 50–70%; however, only 10–23% of patients present with disease amenable to HR or LT [9–11]. Most patients present with advanced HCC and face 1-year survival of 15–39% with limited treatment options [12, 13]. Nevertheless, marked advances in targeted and systemic therapies for HCC have been made over the last decade and have been reviewed elsewhere [14, 15]. Herein, we will primarily discuss surgical intervention, with a specific focus on the role of laparoscopic and minimally invasive surgery (MIS), for the treatment of HCC.

Surgical Therapy for HCC

Surgical therapy for HCC comprises hepatic resection or liver transplantation. LT shows excellent outcomes, with 5-year survival rates of 60–70% [16]. LT, however, is limited to patients within Milan criteria, defined as up to three lesions, each < 3 cm in diameter, or a single lesion < 5 cm in diameter, and no extrahepatic manifestations or vascular invasion [17, 18]. Patients with HCC who undergo LT within Milan criteria have similar 5-year survival as those with non-HCC etiologies of liver disease [19]. Despite this excellent overall survival, approximately 10–20% of patients will develop tumor recurrence with a median recurrence free survival (RFS) of 12–16 months and increased mortality risk of death [20–22]. Patients who do not meet Milan criteria have undergone LT using expanded criteria, such as the University of California-San Francisco (UCSF) criteria described in Yao et al. in 2001, the "Seven-Up" criteria by Mazzaferro and colleagues, or the "5–5 Rule" from the University of Tokyo [23–25]. Together, they have reported 5-year survivals of 71.2% and higher. Nevertheless, current guidelines in the United States for awarding exception points to patients on the LT waitlist continue to follow Milan criteria.

Given the strict guidelines for LT waitlisting in the US, and the known increased risk of recurrence for patients with disease burden outside of Milan criteria, HR remains a viable option for patients with preserved liver function. HR in patients who fall within Milan criteria shows a similar 5-year survival of 60–70% [26]. According to both American Association for Study of Liver Disease (AASLD) and European Association for the Study of Liver (EASL) guidelines, hepatic resection should be reserved for patients with tumors confined to the liver and Child–Pugh-Turcotte class A liver function, with society-specific considerations for tumor number and size [27]. Historically, patients with portal hypertension were not considered for HR due to increased morbidity and mortality [28–30]. However, recent advances in surgical technique and post-operative care have been associated with non-inferior outcomes [31–33], making the presence of portal hypertension a point of controversy rather than contraindication in hepatic resection. Nevertheless, underlying liver dysfunction, such as that identified by the model for end-stage liver disease (MELD) score, remains a predictor of perioperative mortality for patients and may be used to guide patient selection [32].

In concert with the presence of underlying liver dysfunction, the extent of resection is a major determinant in the decision to proceed with surgical resection. Patients without any underlying liver dysfunction can typically tolerate partial hepatectomies as long as at least a 20–30% functional liver remnant (FLR) is preserved. Those with cirrhosis within, and almost always not beyond, BCLC stage A require at least 40% FLR to avoid post-operative liver failure [34]. Between these two extremes of liver disease, patients with steatosis, cholestasis, or chemotherapy-associated liver injury (particularly with oxaliplatin and irinotecan) may require 35–40% FLR to reduce risk of post-operative complications [35–37]. As such, the extent of safe HR is closely associated with liver function and the presence of portal hypertension. While there remains ongoing debate between anatomic and non-anatomic approaches, resections of large tumors or those with macrovascular invasion may be undertaken if these safe principles are met [38–40].

Role of Laparoscopy in Liver Surgery

Surgical therapy with HR remains a first-line therapy for patients with HCC and compensated liver function [41]. The first laparoscopic liver resection was reported in 1991 [42]. Despite passage of more than two decades, however, widespread adoption of minimally invasive techniques in liver surgery has been slow, partly due to technical complexities, risk of bleeding, and oncologic concerns. These were issues brought up during two international consensus conferences that have occurred to provide summaries of the status and perspective of laparoscopic liver surgery—Louisville, KY, USA, in 2008 and Morioka, Japan, in 2014 [43, 44]. Fortunately, advances in technique, instrumentation, increased experience, and accumulation of data have contributed to increased utilization of minimally invasive techniques in liver surgery. The following sections will focus on laparoscopic techniques in liver surgery and describe both oncologic outcomes and patient-centered metrics.

Surgical Resection Versus Other Treatment Modalities

Multiple different options for treatment exist for patients with BCLC stage 0/A/B disease, including local–regional therapies such as trans-arterial radioembolization (TARE) with yttrium-90 (Y90), or chemoembolization (TACE), ablative approaches, percutaneous ethanol injection, or surgical intervention [14]. Ablative approaches include radiofrequency ablation (RFA) or microwave ablation (MWA) and may be accomplished percutaneously under image guidance with either computed tomography (CT) or ultrasound (US). RFA may also be done laparoscopically (technique described below). Ablative techniques have proven efficacious for patients with a low tumor burden (e.g., less than four lesions, tumors < 3 cm in diameter), showing similar time to recurrence and patient survival in multiple randomized controlled trials (RCTs) comparing RFA and MWA [45–47]. Transarterial therapies include chemoembolization (TACE) and radioembolization (TARE). TACE is the most commonly used therapy for HCC and requires accession of the hepatic artery, usually through the femoral artery in a percutaneous method, to deliver cytotoxic chemotherapy directly into the tumor bed and concurrent embolization of the feeding arteries to cause ischemia [48, 49]. Similar to TACE in approach, TARE delivers radioactive microspheres containing β-emitting yttrium-90 isotopes to deliver local radiation to the tumor bed. A recent meta-analysis comparing TACE and TARE treatment strategies showed TARE resulted in a longer time to progression than TACE (17.5 months vs 9.8 months) but no difference in overall survival (hazard ratio 0.90, 95% confidence interval [CI] 0.70–1.16) [50]. Furthermore, the current era of immunotherapy has dramatically changed the landscape of locoregional therapies and has been recently described by Llovet et al. [51]. Nevertheless, both treatment options may be used as bridging therapies to either HR or LT and may provide the benefit of stimulating growth of FLR [52–55].

Given multiple potential treatment modalities and variations in center-specific approaches due to availability of resource and expertise, there has remained significant debate about the role of surgery in the management of HCC, particularly early HCC. Lee et al. compared outcomes between RFA and HR amongst well-compensated (Child–Pugh-Turcotte class A) patients with a single, small (< 3 cm) HCC and found RFA was associated with worse recurrence-free survival (hazard ratio 1.698, 95% CI 1.177–2.448, $p = 0.005$), but no difference in overall survival between the two groups [56]. RFA is additionally associated with decreased complication rates and shorter hospital stays in the setting of equivalent survival [57, 58]. In a meta-analysis by Li et al., 13,147 patients with HCC (6727 RFA and 6420 HR) were evaluated for differences in RFS and OS based on RFA or HR [59]. Consistent with prior results, for small tumors (≤ 3 cm), they showed higher rates of RFS amongst those undergoing HR at 1, 3, and 5 years post-procedure. Additionally, they showed improved overall survival at 3 and 5 years post-procedurally with HR compared to RFA (5-year odds ratio 0.566, 95% CI 0.423–0.758). Interestingly, for larger tumors (> 3 cm), improved 1- and 3-year RFS persisted with surgical resection; however, there was no difference in 1- and 3-year overall survival between the two groups.

Surgery has also been compared to TACE and TARE. Zhang et al. evaluated the utilization of TACE or HR for solitary HCC lesions and found comparable overall survival between the two treatments at 1, 3, and 5 years post-procedure across all patients, but a statistically significant improved survival with HR for tumors ≤ 6 cm [60]. Interestingly, they found that HR was associated with an increased rate of major complications (Clavien-Dindo ≥ 3, 3.9% with TACE vs 17.4% with HR, $p < 0.001$), while TACE was associated with a higher rate of minor complications, primarily nausea, fever, and pain (Clavien-Dindo ≤ 2, 43.3% with TACE vs 13.8% with HR, $p < 0.001$). A recent study of patients with more advanced disease (BCLC stage B) found higher overall survival in patients who underwent surgical resection compared to patients who underwent TACE or combined TACE + RFA (HR vs TACE, hazard ratio for survival 3.10, 95% CI 2.15–4.46, $p < 0.001$) [61]. In a meta-analysis of nine studies, Gui et al. compared all three options—TACE, RFA, and surgical resection—for HCC and found that no statistically significant difference in 1-year disease free survival, but did show an increased rate of local tumor progression for TACE and RFA. Additionally, they showed lower complication rates with TACE or RFA compared to surgical intervention [62]. Still, these studies have their own limitations and prevent definite conclusions.

Ultimately, surgical intervention remains a cornerstone therapy for HCC with decision-making determined by patient-related factors—surgery is indicated for patients with BCLC stage 0/A and select stage B patients, even with larger tumors, or those with more complicated disease. Tumors which are located close to major vessels which may be negatively impacted by the heat sink associated with RFA leading to incomplete treatment and risk tumor progression [63, 64]. Patients with portal vein invasion or tumor thrombus have also been shown to benefit from surgical resection compared to TACE [65]. Underlying liver disease also is a contraindication to RFA, as elevated pre-procedural bilirubin (2.5 mg/dL) has been associated with increased morbidity and mortality following RFA for HCC [66]. Considering these factors in patient selection, hepatic resection may be undertaken for HCC in many patients with good outcomes.

Laparoscopic and Open Approaches to Liver Surgery

The benefits of laparoscopic surgery have been reported across multiple surgical procedures and include reduced pain and shorter length of stay, while maintaining equivalent outcomes. Liver surgery is unique, as the anatomic location of the liver, tucked beneath the rib cage in the right upper quadrant, and large size makes surgical access difficult. Open surgery typically requires a large incision, often involving the subcostal region(s) with division of the rectus muscle, all of which carry the risk of post-operative complication of wound infection and incisional hernia, along with pain control issues and prolonged recovery. In appropriately selected patients, laparoscopy may offer a more direct approach with good visualization of the liver and reduced need for manipulation, which in turn may cause less parenchymal damage [67, 68].

Perhaps the most important outcome for any surgery performed for cancer is RFS and overall post-operative survival. Lee et al. performed a propensity-matched analysis on 116 patients who underwent HR for HCC and also showed no difference in 1-, 3-, and 5-year RFS and overall survival between open and laparoscopic approaches [69]. In a case–control study by Memeo et al., laparoscopic HR was associated with an increased rate of R0 resection compared to open resections (95% vs 85%, $p = 0.03$) with similar mortality, RFS, and overall survival [70]. Cai et al. performed a meta-analysis to evaluate use of laparoscopy for recurrent HCC and found no difference in operative time or 90-day mortality between the two groups [71].

Laparoscopic approach is feasible in appropriately selected patients with cirrhosis. Ciria et al. performed a systematic review and meta-analysis comparing laparoscopic and open HR for patients with HCC, showing that amongst patients with Child–Pugh class A cirrhosis, laparoscopic HR was associated with lower complication rates and no difference in RFS or overall survival [72]. Patients with signs of decompensation may have increased risk with laparoscopic surgery, as Fuji et al. demonstrated a 35.3% rate of conversion to open surgery in patients with Child–Pugh class B cirrhosis [73]. In contrast, Morise et al. showed comparable outcomes between patients with severe and mild cirrhosis who underwent laparoscopic resection of surface HCC tumors [74]. In a propensity-matched retrospective study, Troisi et al. identified 200 patients with Child-Turcotte-Pugh (CTP) class B cirrhosis who underwent HR (100 laparoscopic versus 100 open) and showed similar 90-day mortality (4% laparoscopic vs 2% open) and no difference in 5-year RFS or overall survival. Additionally, they reported that laparoscopy was associated with decreased blood loss, reduced morbidity, and shorter median hospital LOS (7.5 days for laparoscopy vs 18 days for open) [75].

Patient-centered outcome measures are also improved with laparoscopic approaches. Complication rates with laparoscopic HR are consistently lower than with open HR. DiSandro and colleagues found major (Clavien-Dindo class III/IV) complications in only 5.3% of patients undergoing laparoscopic HR compared to 18.7% of patients undergoing open HR [76]. Similar findings have been reported by other groups as well [77, 78]. Lower blood loss has been associated with laparoscopic HR when compared to open approaches [71, 76, 79]; however, in two reports of major liver resections, blood loss was equivalent between the groups (Han et al., Sposito et al.) indicating that some benefits of the laparoscopic approach may be limited to minor resections. Nevertheless, patients undergoing laparoscopic HR often have shorter LOS than following open resection, a finding which has been repeatedly reported [70–72, 76, 79–81]. The aforementioned study by Cai et al. showed these patient-related outcomes persisted even in those undergoing laparoscopic HR for recurrent HCC, again showing a lower rate of complications, decreased blood loss, and shorter hospital LOS with laparoscopic approach [71]. Lastly, Cipriani et al. compared laparoscopic HR in CTP class A and B patients and found similar blood loss volume, complication rate, and rate of post-hepatectomy liver failure (PHLF) in both groups [82].

Non-resection Applications for Laparoscopic Liver Surgery

Perhaps the most basic application of laparoscopy in liver surgery is the use for diagnosis and evaluation of the abdomen in patients with indeterminate liver lesions or those with concern for extrahepatic disease. In cases where a liver biopsy is needed, laparoscopic surgery can offer advantages over interventional radiology (IR)–based percutaneous approaches. Percutaneous liver biopsy has been associated with risk of bleeding that ranges from 0.9 to 10.9%, with 0.1–4.6% of events being reported as major bleeds [83]. Bile leak and, to a much smaller extent, tumor seeding from needle tracks are also concerns. Laparoscopy offers the benefit of direct visualization with the ability to achieve adequate hemostasis and bile stasis [84]. Utilization of intraoperative US (IOUS) improves localization and characterization of liver lesions and allows performance of core needle biopsy under image guidance with the benefit of evaluating the liver for bleeding complications following needle removal [85, 86]. Notably, IOUS has been found to identify new and previously undetected lesions in a small number of patients at time of surgery which may not be detected using computed tomography or ultrasound with percutaneous approach [87, 88]. In these studies, many newly identified lesions were small enough (< 3 cm) to be amenable to ablation at time of surgery.

Laparoscopy can also be used to perform ablation of HCC lesions. Overall 1-year survival rates for lap-assisted RFA range from 72.3 to 78.0%, and this technique may be applied in patients with more advanced cirrhosis [89–91]. Laparoscopic approach for ablation typically involves use of general anesthesia. Patient positioning and port placement are described in Fig. 1. Ablation probes are typically introduced through a large angiocatheter placed separately from the laparoscopic ports which provides an ideal angle for access to the lesion. The utilization of IOUS does require the availability of a 12-mm trocar, but allows accurate placement of ablation probes within the target lesions under direct visualization.

Laparoscopic Liver Surgery for Hepatic Resection

Two primary approaches to laparoscopic liver resection exist—total laparoscopy and hand-assisted laparoscopy. In a total laparoscopic approach, multiple ports offer adequate views of target areas. Port placements are shown in Fig. 1A, B for a total laparoscopic approaches to right and left liver resections, respectably. Following parenchymal division, specimens may be removed through a variety of incisions, including upper midline, lower midline, and Pfannenstiel incisions. Figure 2 shows representative images from a total laparoscopic resection of a segment 6 lesion utilizing both a hydrojet dissector (Fig. 2B) and argon-beam coagulator (Fig. 2C) as dissection methods.

A hand-assisted approach using a subcostal incision for hand-port placement has been previously described [92, 93]. Another approach involves an upper midline incision (~ 7–8 cm extending inferiorly from the xiphoid) for the hand-port and placement of a supra-umbilical 12-mm port and a right upper quadrant 5-mm port (Fig. 1C). Initially, the falciform ligament and any adhesions are divided under direct visualization through the upper midline incision. Using a hand-assisted approach and an energy device (our preference is a 5-mm LigaSure™, Medtronic, Minneapolis, MN, USA), the right lobe of the liver is fully mobilized by taking down lateral, inferior, and posterior attachments until the inferior vena cava is visualized medially and the right hepatic vein is visualized supero-posteriorly. After lysing any remaining adhesions, the operation is converted to an open approach through the upper midline incision with removal of the hand-port. The liver can now be mobilized medially, and the remainder of the portal dissection and parenchymal transection is performed under direct visualization, with removal of the specimen through the same incision. First reported for utilization in right lobe hepatectomy for living donor liver transplantation, this technique showed an operative time of 235 min and an associated length of stay of 3 days [94]. The learning curve for laparoscopic liver resections was previously reported as ~ 60 cases [95]; however, this number may have changed with increasing use of laparoscopy and minimally invasive techniques for other surgical indications. Additionally, the utilization of IOUS is integral to performing an adequate and safe liver resections [96].

The choice of approach is often dictated by lesion characteristics. Laparoscopic surgery was initially used primarily for anteriorly located tumors; however, advancements in technique have made even posterior segmental resections possible. Posterior resections are considered major

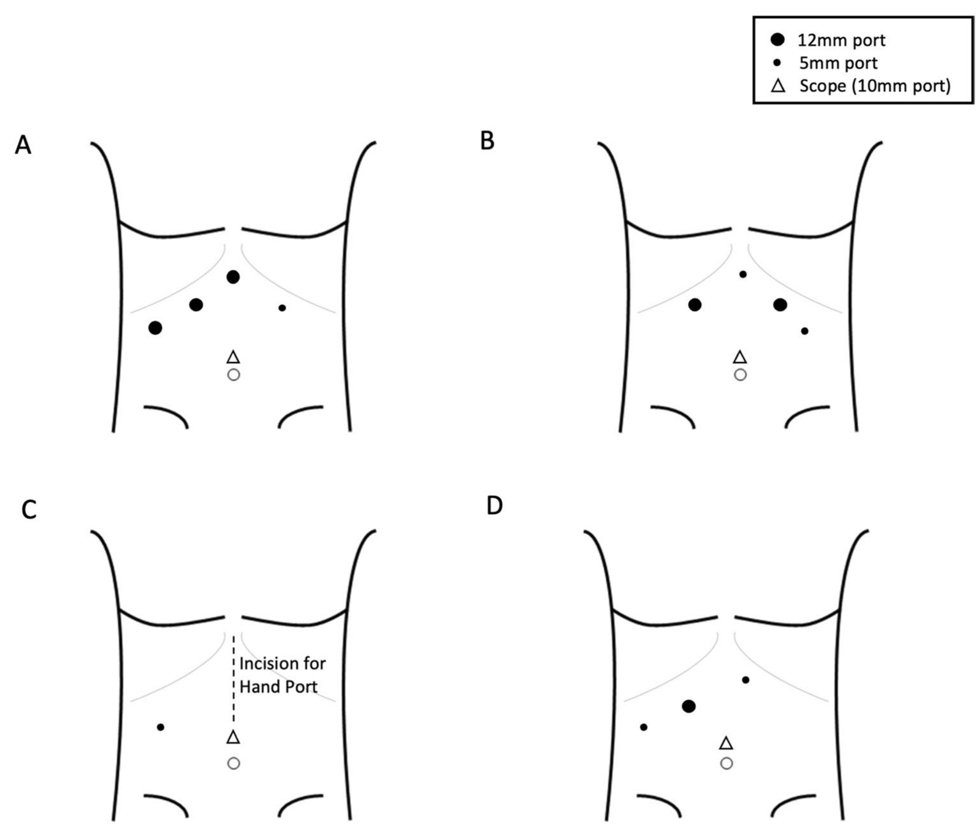

Fig. 1 Port placement for laparoscopic liver surgery. Port placement for laparoscopic liver surgery is dependent on location of the lesion and magnitude of resection. Total laparoscopic approaches utilize 12-mm and 5-mm ports with placement dependent on **A** right hepatic resection and **B** left hepatic resection. **C** Hand-assisted approach utilizes an upper midline incision with placement of gel port and scope and single 5-mm port, with eventual elongation of the upper midline incision. **D** Laparoscopy for diagnostic and ablation purposes utilize fewer ports with ablation probes inserted through an angiocath inserted into the abdominal wall

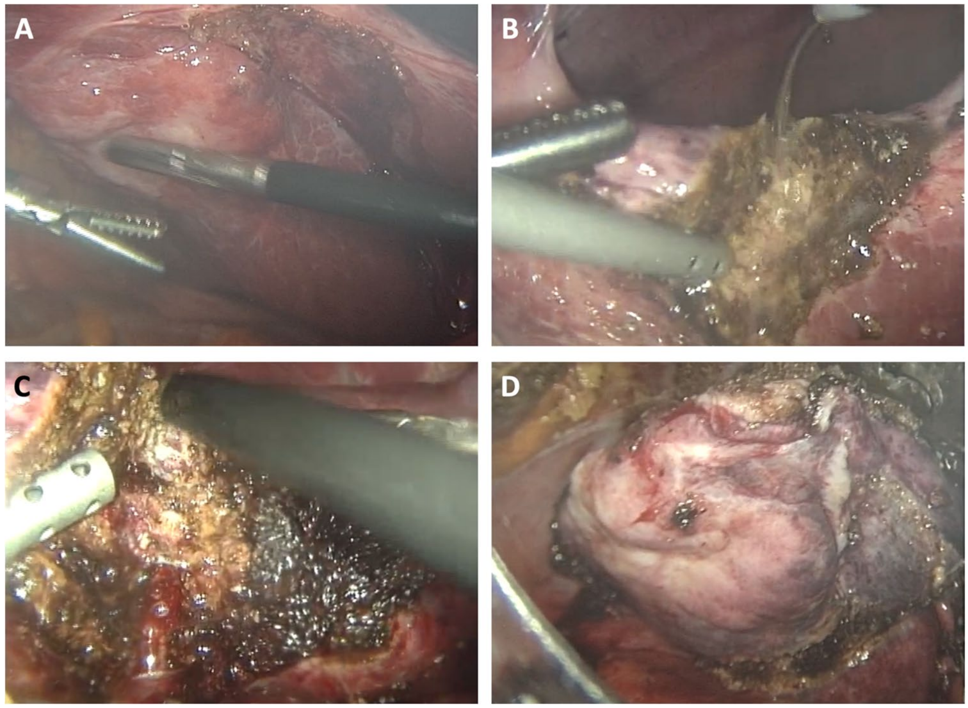

Fig. 2 Laparoscopic segment 6 resection. An isolated HCC lesion in segment 6 (**A**, **D**) is resected by total laparoscopic approach utilizing both hydrojet dissector (**B**) and argon beam coagulation (**C**) as methods of parenchymal transection

resections due to longer operative times and increased rates of conversion to open surgery [97–99]. However, multiple studies have shown laparoscopic approaches to posterior segment lesions are safe with equivalent complication rates, hospital LOS, and overall survival [98, 100, 101]. Changes in patient positioning or operative strategy have been described to improve exposure and visualization of the posterior segments with good outcomes [102, 103].

The Asian-Pacific Association for Surgery of the Liver (APASL) guidelines suggest that all tumors without extrahepatic metastases are potentially resectable regardless of number and size of lesions [104–106]. Patients with multiple tumors are still candidates for HR with a laparoscopic approach [107]. A recent RCT showed improved OS for patients with multiple HCC lesions outside of Milan criteria when undergoing HR compared to TACE [108]. Large HCC lesions can also present as difficult resections; however, successful results have been reported for laparoscopic resection of large tumors, even those over 10 cm in diameter, despite being technically demanding [109–112]. To date, as experience grows and techniques become refined, the limits of laparoscopic and minimally invasive approaches are continually redefined.

Limitations and Complications of Laparoscopic Liver Surgery

Laparoscopic HR is not without its limitations. PHLF remains a significant concern following laparoscopic partial hepatectomy, as it does for open HR. Rates vary with extent of resection, but range from 0.7 to 35% [113]. Avoiding PHLF is achieved through both patient selection and maintenance of an adequate FLR. As previously mentioned, patients with cirrhosis or underlying liver dysfunction should have an FLR of at least 40%, while those with normal livers may require only 20 to 30% FLR [114]. Methods to increase the FLR include portal vein embolization (PVE), TACE or TARE, hepatic vein embolization, ischemic preconditioning, and even associating liver partition and portal vein ligation for staged hepatectomy (ALPPS) procedure, and have been reviewed elsewhere [115]. More directly related to the laparoscopic approach, the risk of gas embolism from abdominal insufflation is present but low, such that overall risks compared to open surgery are similar [116]. Given the limited mobility with laparoscopic approach, control of bleeding may be more difficult; however, application of intracorporeal suturing, clipping, use of energy devices, and use of hemostatic agents provide adequate measures for performance of a safe hepatectomy [117]. In general, the laparoscopic approach is often avoided in patients which require significant vascular resection or reconstruction.

Robotic Approaches in Liver Surgery

The technical advantages of robotic liver resection for hepatocellular malignancy underscore the benefits of robotic surgery at large: improved three-dimensional (3D) visualization, increased degrees of freedom of movement with articulating instruments, ease of performance of intracorporeal suturing, and overall better instrumentation including the Vessel Sealer, SynchroSeal, various staplers, suction irrigator, and Firefly™ technology, to name a few [118, 119]. The improvements resulting from the ability to see tissue through highly magnified 3D high-definition vision, coupled with the ability to use IOUS simultaneously with picture-in-picture software, cannot be overstated. Traditionally, difficult areas of liver to reach laparoscopically, such as posterior segments and lesions near the diaphragm, can be approached more readily with the robotic platform. Difficult mobilization of the liver (e.g., right lobe) can be performed easier robotically than laparoscopically. Prior operations are less of a challenge thanks to the more versatile ability of the robotic techniques in lysis of adhesions and dealing with difficult dissections. Re-operations to investigate concerns for bleeding, bile leak, bowel injury, or other complications can be done (and often completed) robotically. Current "missing" robotic tools in liver surgery can, for now, be augmented by use of available laparoscopic instruments through appropriately placed assistant ports [120]. Finally, robotic approaches to liver resection in HCC may offer future additional advantages such as better tumor localization through 3D pairing of pre-operative imaging with computer-guided resection, better instrumentation, and more versatile "live" patient positionings through pairing of robotic platform with the surgical bed. One current limitation in robotic liver resection remains the lack of haptic feedback, while a highly mobile, 3D, high-definition robotic camera can compensate for this to a great extent. Eventually, it is very likely that haptic feedback will be added to the platform through technological advances that are current under investigation.

The learning curve of robotic liver resection appears to be similar to laparoscopic liver resection, but ultimately depends on underlying surgeon familiarity with the robotic platform. One series described initial competency following 15 robotic liver resections accompanied by decreasing operative duration and hospital stay, intermediate improvement after 25 additional resections resulting in decreased intraoperative blood loss, and mastery of increasingly complex robotic liver resections by 92 cases [121].

Robotic liver resection has demonstrated comparable patient outcomes to both open and laparoscopic liver resection. In a propensity score-matched comparison of patients undergoing robotic and open liver resection for HCC ($n = 106$ per group) between high volume centers in the United States and Europe, robotic liver resection patients had a longer operative time (295 vs 200 min; $p < 0.001$) but shorter post-operative inpatient hospital stay (4 vs 10 days; $p = 0.002$) [119]. Comparison of oncologic outcomes demonstrated equivalent 90-day survival (99.1% vs 97.1%, $p = 0.33$) and cumulative incidence of death related to tumor recurrence (8.8% vs 10.2%; $p = 0.64$) [119]. Another series comparing robotic ($n = 71$), laparoscopic ($n = 141$), and open ($n = 157$) liver resection for BCLC stage 0-A HCC demonstrated no difference in 5-year DFS, OS, or post-operative complications [122]. Finally, a meta-analysis comparing robotic liver resection to open and laparoscopic approaches found similar patient survival and complication rates between the approaches, but importantly emphasized the need for randomized controlled trials conducted independent of industry sponsorship [123].

Still, perhaps the greatest limitation in robotic surgery is the availability of the resource due to high costs of acquisition and maintenance. It is to be noted that for the last several years, our practice has transitioned to primarily robotic approaches for surgical treatment of hepato-pancreato-biliary issues, including surgical management of HCC. We strongly believe that robotic surgery offers significant advantages over laparoscopic surgery and represents our preferred technique.

Conclusions

Hepatic resection for HCC, and many other indications, is a technically demanding operation, often performed in patients with multiple pre-existing conditions. Successful completion of this operation requires appropriate patient selection and operative planning. Minimally invasive surgery, both laparoscopic and robotic platforms, offers safe and effective approaches for diagnostic biopsies, ablative therapies, and multi-segmental hepatic resections. Furthermore, there may be significant benefits to patients in post-operative recovery without sacrificing oncologic outcomes.

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Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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