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REVIEW ARTICLE

Technique of robotic left hepatectomy : how we approach it

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Abstract

Minimally invasive technique has been adopted as the standard of care in many surgical fields within general surgery. Hepatobiliary surgery, however, is lacking behind due to the complex nature of the operation and concerns of major bleeding. Several centers suggested that inherent limitations of conventional laparoscopy precludes its wide adoption. Robotic technique provides solutions to these limitations. In this study, we report our standardized technique of robotic left hepatectomy. We discuss aspects of robotic hepatectomy and describe our standardized approach for robotic left hepatectomy. A video is attached to this article. A 76-year-old man with a 4.5 cm biopsy-proven hepatocellular carcinoma was taken to the operating room for a robotic left hepatectomy. His past medical and surgical history was only consistent with hypertension and diabetes. Robotic extrahepatic glissonian pedicle approach was applied to gain inflow control. Left hepatic artery and portal vein were individually dissected and isolated prior to division. An intraoperative robotic ultrasound was utilized to ensure negative resection margins. Left hepatic vein was transected intrahepatically using a laparoscopic Endo GIA stapler. Segment 2,3, and part of 4 were removed. Operative time was 180 min without intraoperative complications. Estimated blood loss was less than 50 cc. The patient was discharged home on postoperative day 3. The use of robotic technology during complex hepatic resections such as left hepatectomy is safe and feasible. This approach provides an alternative technique in minimally invasive liver surgery.

Keywords Robotic hepatectomy · Robotic liver resection · Technique of robotic left hepatectomy

Introduction

Until the 1980s, perioperative mortality following open liver resections was approximately 20%, mainly related to significant intraoperative hemorrhage [1, 2]. As hepatectomy became safer as a result of better understanding of liver anatomy, better instrumentation, improved perioperative anesthesia and postoperative care, minimally invasive techniques began to gain popularity in the mid 1990s. Reduced postoperative incisional pain, decreased postoperative narcotic requirements, lower cardiopulmonary and wound-related complications, decreased length of hospital stay and improved cosmesis have transformed minimally invasive hepatectomy to be the preferred approach when technically feasible, with at least similar short- and long-term oncologic outcomes when compared to the traditional 'open' approach [1–6].

The conventional laparoscopic approach, however, has inherent limitations, such as limited range of motion, amplification of physiologic tremor, often suboptimal visualization, difficulty of suturing in certain locations, reduced ergonomics, and a steep learning curve. The robotic approach provides a better solution for the technical limitations of the conventional laparoscopic technique [7–12]. The first report of robot-assisted liver resection was published in 2006 by Ryska et al. [13]. Today, the robotic system offers seven degrees of freedom with Endowrist® technology, better ability to reach high posterosuperior (i.e., segment 7 and 8) lesions, enhanced suturing capability, superior visualization with a three-dimensional camera system, filtration of physiologic tremor, and superior surgeon ergonomics. These features allow for more precise identification and complex dissection of inflow/outflow vessels and biliary ducts, both

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intrahepatically and extrahepatically. While most minimally invasive hepatectomy series predominantly contain peripheral non-anatomical hepatectomies, the extrahepatic Glissonian pedicle approach (Takasaki method) leads the modern minimally invasive techniques for major hepatectomy in both cirrhotic and non-cirrhotic patients. Detailed description of the technical approach during robotic left hepatectomy had only been discussed limitedly in the literature. Herein, we describe our surgical technique of robotic left hepatectomy for hepatocellular carcinoma.

Materials and methods

Aspects of minimally invasive hepatectomy are discussed. Our standardized surgical approach of robotic left hepatectomy is described. A video is attached with this article.

Patient assessment and operative strategy

Indications and preoperative evaluation for robotic hepatectomies are similar to those of open hepatectomy. Imaging of the liver is best obtained with triphasic liver-computed tomography (CT) scan or enhanced magnetic resonance imaging (MRI). Percutaneous liver biopsy by an interventional radiologist is generally reserved only for patients with tumors of diagnostic uncertainty, despite high-quality imaging. Evaluation of future liver remnant volume and patient general health condition are similar to those of open hepatectomy. Decision to perform a hepatectomy using the robotic technique is mainly influenced by tumor location, size, vicinity to the vital vascular/biliary structures, and experience of the robotic team. Both the surgeon at the console and bedside assistant must be proficient in open and minimally invasive hepatectomy techniques. They should ideally be interchangeable throughout the operation. Central and high posterior liver lesions provide technical challenges and require experience in minimally invasive techniques, particularly for exposure. Technical challenges with liver mobilization, hilar dissection, parenchymal transection, and hemostasis can be minimized by optimal patient positioning, effective port placement, proper use of surgical instruments, and fluent communication between the anesthesia and surgical teams. Difficult dissections requiring significantly prolonged operative time, failure to progress, and significant intraoperative bleeding, are several indications for conversion to the ‘open’ approach. The anesthesia team must maintain a low central venous pressure (<5 mmHg) via a preoperatively placed jugular or subclavian vein central line, especially during the parenchyma transection phase. Additionally, temporary inflow occlusion technique with Pringle maneuver is sometimes necessary when significant bleeding is encountered. Therefore, we routinely place a large vessel loop around the hepatoduodenal ligament in all major hepatectomies for the potential necessity of performing the Pringle maneuver.

Operative technique

Step 1. Patient positioning and trocar placement

The patient is positioned supine on the operating room table and general endotracheal anesthesia is administered. A foley catheter and a naso-gastric tube are inserted for urinary bladder and stomach decompression. In major hepatectomy, an arterial line and a central venous (internal jugular or subclavian vein) catheter are routinely placed. The bedside surgeon stands to the patient’s right and the scrub nurse stands to the patient’s left side. Prior to port placement, the operating room table is positioned in a slight reverse Trendelenburg position (up to thirteen degrees) and a left or right tilt for a lesion located in the right or left liver lobe, respectively. The newest version of daVinci Xi® robotic system (Intuitive Surgical Inc., Sunnyvale, CA, USA), can be paired with the operating room bed before docking. This way, bed repositioning during the operation (when necessary during the later stages of the operation) is simple, without the need of undocking the robotic system. The abdomen is prepped using an alcohol-based solution and a betadine impregnated plastic drape is applied after 3 minutes of drying time. Prior to making an incision, 5 cc of 0.25% Marcaine ™ (AstraZeneca, Wilmington, DE) with epinephrine (1:1000) is injected into the umbilicus for local anesthesia. An 8 mm vertical incision is made in the umbilicus without an insult to the umbilical ring. A robotic trocar is inserted and pneumoperitoneum is established with CO_2 to 15 mmHg. The daVinci Xi® robotic camera is inserted and diagnostic laparoscopy is undertaken.

Once diagnostic laparoscopy documents no contraindication to tumor resectability, the remaining robotic trocars are placed: the second port at the level of the umbilicus along the right midclavicular line, the third at the level of the umbilicus along the left midclavicular line, the fourth trocar along the left anterior axillary line slightly cephalad to the level of umbilicus (Fig. 1). An AirSeal® 5 mm insufflation trocar (Surgiquest, Milford, CT) is placed in the right upper quadrant at the subcostal margin and the anterior axillary line or alternatively through the Gelpoint® Advanced Access Platform (Applied Medical, Rancho Santa Margarita, CA) which is placed in the right lower quadrant caudal to the umbilicus between the umbilicus and the second trocar for the bedside surgeon to work and to extract the liver specimen at the end of the operation (Fig. 1). The bedside surgeon must be able to reach the dissection/transection area for suctioning, compression, clipping, and stapling without difficulty. For example, for a tall patient, all trocars would be

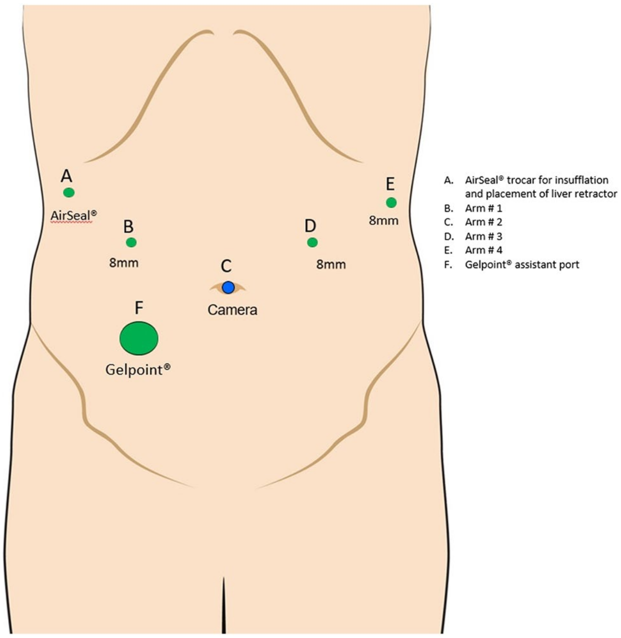

Fig. 1 Trocar placement

moved cephalad, except for the umbilical port. After docking of the daVinci Xi® robotic system, a fenestrated bipolar (arm # 1), a hook cautery (arm #3), and a non-traumatic bowel grasper (arm #4) are placed into position. A laparoscopic suction device is handled by the bedside surgeon.

Step 2. Liver mobilization

The operation begins with division of the round and falciform ligaments using the robotic hook cautery. The left coronary and triangular ligaments are divided using the hook cautery. Do not injure with branches of the phrenic vein, often located nearby. Access into the lesser sac is achieved by dividing the gastro-hepatic ligament medially with careful attention to an accessory or replaced left hepatic artery, which are present in about 10–15% of patients. The gastrohepatic ligament is opened all the way cephalad, towards the origin of the left hepatic vein. The goal is to obtain a complete mobilization of the left lobe of the liver (Fig. 2).

Step 3. Portal dissection

Dissection of the portal triad begins by appropriately lifting the inferior aspect of the liver cranially using the non-traumatic bowel grasper (arm #4). The common hepatic artery or, preferably, the proper hepatic artery is identified in the hepato-duodenal ligament distal to the gastroduodenal artery takeoff. The left hepatic artery is then dissected and isolated using the hook cautery (Fig. 3). A clamping test should be routinely performed to visually ensure the

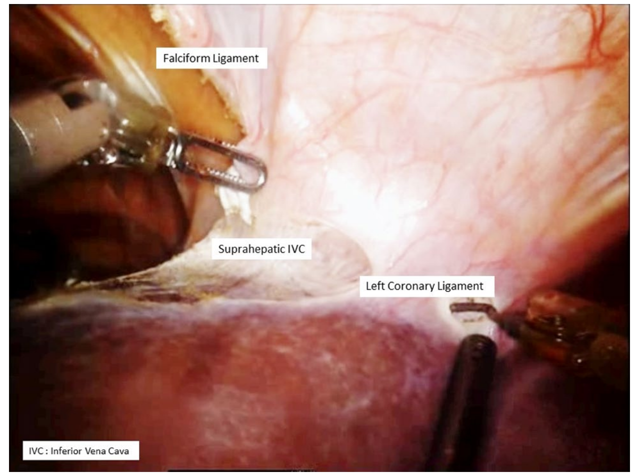

Fig. 2 Liver mobilization

presence of an intact flow in the right hepatic artery prior to clipping of the left hepatic artery using medium size WECK Hem-o-lok® clips (Teleflex Medical, Durham, North Carolina, USA). Intraoperative Doppler ultrasound may facilitate accurate identification of the left and right hepatic arteries. The long transverse portion of the left portal pedicle allows a technically safer anatomical dissection of the left-sided inflow relative to the right-sided inflow. Once the left hepatic artery is divided with robotic scissors between the clips, the left portal vein is then carefully dissected, isolated and subsequently clipped using large size WECK Hem-o-lok® clips, two proximally and one, preferably two, distally prior to division (Fig. 4). A ligature about the left branch of the portal vein may facilitate subsequent clip application and division.

Small branches to the caudate lobe sometimes need to be divided to gain adequate space for isolation of the left portal

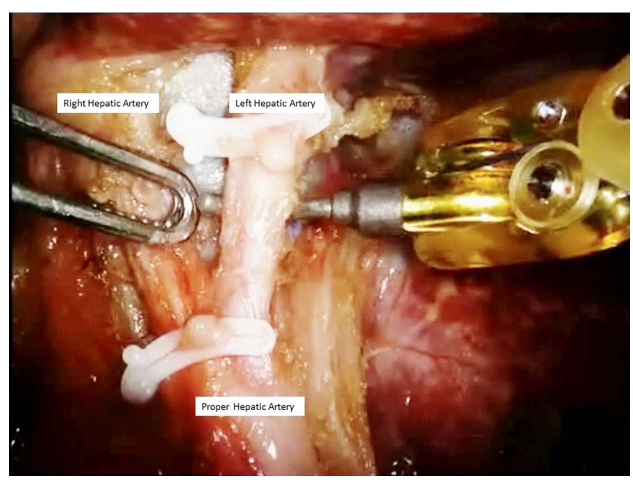

Fig. 3 Isolation of the left hepatic artery

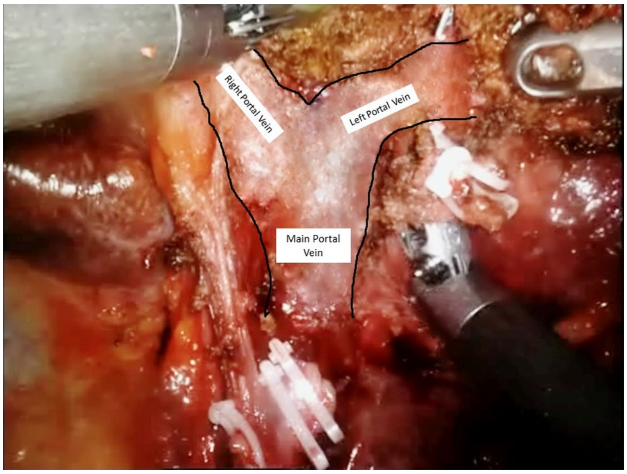

Fig. 4 Isolation of the left portal vein

vein; these are controlled with clips. The left hepatic bile duct is divided using a laparoscopic Endo GIA™ 60 mm linear stapler (Medtronic, Minneapolis, MN, USA) at a later stage during the liver parenchymal transection to ensure no injury to the right hepatic duct. Division of the left hepatic duct should be close to the base of the umbilical vein and away from the portal bifurcation. It is important to recognize that the right posterior sectoral bile duct from segment 6 and 7 empties into the left hepatic duct in approximately 13–19% of the population [14, 15], therefore, it is safer to divide the left hepatic duct close to the junction of the transverse and umbilical portion of the left portal pedicle.

Step 4. Parenchymal transection

The line of parenchymal transection is marked with hook cautery following a demarcation line on the liver surface after inflow division (Fig. 5). Placement of figure-of-eight silk sutures on both sides of the transection plane can be helpful for retraction; however, we do not utilize this method routinely. Use of rubber bands for constant lateral traction has also been described by Choi et al. [16, 17]. Intraoperative ultrasonography must be performed to confirm tumor location and to ensure adequate resection margins. Ultrasonography is also crucial to map the location and trajectory of medium and large-size intrahepatic vessels, especially those that are located along/near the anticipated parenchymal transection plane. The Tilepro™ feature of the daVinci® system is helpful in transferring ultrasonographic images to the console. The liver parenchymal transection begins utilizing a robotic vessel sealer™. The instrument is activated while the jaws are in open position and they are gradually closed as parenchymal coagulation advances (Fig. 6). The bedside surgeon helps obtain exposure and tissue hemostasis, as well as to maintain a proper orientation of the transection plane during the parenchymal

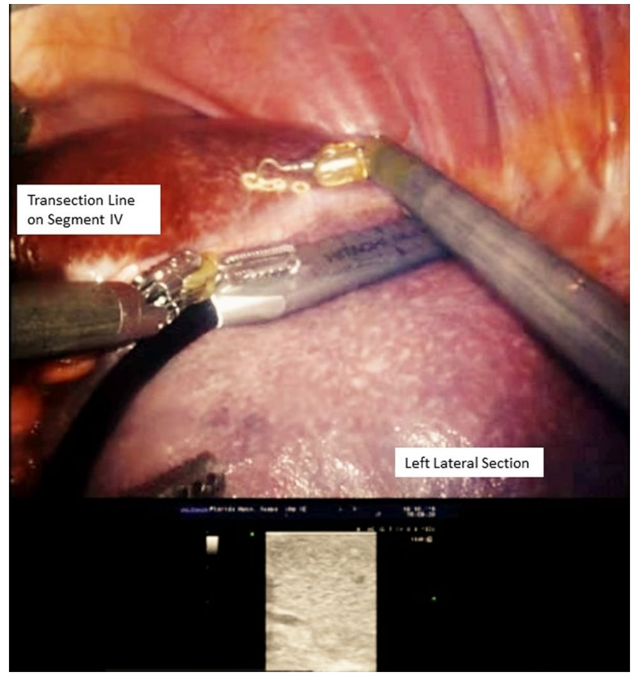

Fig. 5 Planning for parenchymal transection

transection. Large crossing vessels/branches found intrahepatically are secured using clips, applications of the vessel sealer (< 7 mm) or a linear vascular stapler (> 7 mm) applied by the bedside surgeon, or a robotic stapler via trocar #3 (if upsized). Resistance during stapler insertion into the liver should prompt an evaluation whether the stapler is advanced against a significant intrahepatic vascular structure. The stapler should be repositioned approximately a few millimeters above or below the original entry site, to avoid laceration/injury to the intrahepatic vascular structure. Failure to recognize this situation

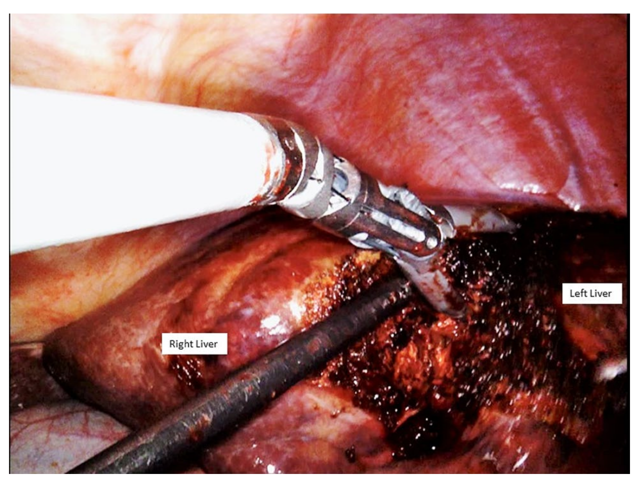

Fig. 6 Liver parenchymal transection

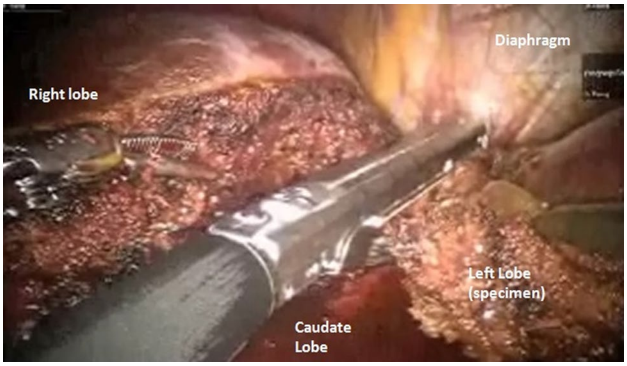

Fig. 7 Intrahepatic division of the left hepatic vein

usually results in major hepatic bleeding with a potential need for an urgent conversion.

Step 6. Division of outflow vessel

The left hepatic vein is divided intrahepatically using a laparoscopic Endo GIA™ 60 mm linear stapler toward the end of the parenchymal transection, aiming the instrument slightly to the left to avoid injuring the proximal middle hepatic vein (Fig. 7). The location of the left hepatic vein has been previously mapped using an ultrasound prior to starting the parenchymal transection. Once the liver specimen is detached from the remaining right hemiliver, thorough hemostasis is obtained and a meticulous search for bile leakage is undertaken along the cut surface prior to closure. If a bile leak is identified from a biliary branch, a careful placement of 3–0 silk sutures in a figure of eight fashion (six inches in length) is effective.

Step 7. Hemostasis and specimen removal

Thermal energy must be carefully applied in areas near the hepatic hilum and vessel staple lines. Aquamantys® (Medtronic Advanced Energy, Portsmouth, NH, USA), a saline-coupled bipolar sealing device provides prompt and effective liver hemostasis, especially when a large cut surface is evident. It is a good practice to decrease the insufflation pressure while observing the liver cut surface for either occult bleeding or biliary leak prior to closure [18]. The resected specimen is placed in a large extraction bag and is removed via the Gelpoint® incision in the right lower quadrant (Fig. 8). It helps to place water-soluble gel on the bag and in the Gelpoint® to facilitate extraction.

Fig. 8 Specimen retrieval

Results

A 76-year-old man with a 4.5 cm biopsy-proven hepatocellular carcinoma was taken to the operating room for a robotic left hepatectomy. His past medical and surgical history was only consistent with hypertension and diabetes. Robotic extrahepatic glissonian pedicle approach was applied to gain inflow control. The left hepatic artery and portal vein were individually dissected and isolated prior to division. An intraoperative robotic ultrasound was utilized to ensure negative resection margins. The left hepatic vein was transected intrahepatically using a laparoscopic Endo GIA™ stapler. Liver segment 2,3, and part of 4 were removed. Frozen section examinations confirmed hepatocellular carcinoma specimen with negative transection margins. Operative time was 180 min without intraoperative complications. Estimated blood loss was less than 50 cc. The patient was discharged home on postoperative day 3. He was seen in the office in 2 weeks postoperatively without any complaints.

Discussion

While the International Consensus Conferences on laparoscopic liver surgery held in Louisville and Morioka led to recommendations that solitary peripheral liver lesions less than 5 cm in size are ideal for minimally invasive techniques, no specific guidelines have been written to date in regards to minimally invasive hepatectomy [19]. The main technical advantage associated with the robotic hepatectomy over the traditional laparoscopic technique is the completion of a higher percentage of major hepatectomies using purely minimally invasive techniques (without conversion to the hand-assisted or hybrid method). In a recent study by Tsung et.al. comparing their single institution laparoscopic and robotic hepatectomies, over 90% of the robotic hepatectomies were accomplished without the need for conversion to the hand-assisted or hybrid technique, in contrast to only 49.1% of cases were accomplished using the purely minimally invasive techniques when conventional laparoscopic approach was used [7]. The technically challenging nature of most hepatobiliary operations provides an ideal application for robotic technology. The robotic system provides superior three-dimensional visualization, better than what is obtained by a high definition modern laparoscope.

Upon review of all published series on robot-assisted hepatectomies, approximately 72% of resections were performed for malignancies [3]. The most common pathology was hepatocellular carcinoma, followed by colorectal liver metastasis and intrahepatic cholangiocarcinoma. Robotic hepatectomy is also indicated for benign and premalignant pathology including by not limited to symptomatic hemangioma, hepatic adenoma, and focal nodular hyperplasia. Thirty-one percent of all robotic hepatectomies were classified as major resections with more than three liver segments removed [9].

It is crucial to have a bedside surgeon who is skilled in advanced minimally invasive hepatectomy. Intraoperative bleeding during parenchymal transection is the primary reason for an immediate conversion. With major intraoperative bleeding which mandates conversion, the bedside surgeon must be able to quickly provide a temporary hemostasis by applying effective compression, undock the robotic system, and gain access into the abdomen. Operating room team training for prompt response in case of major bleeding or other disastrous intraoperative events is essential. Inability to obtain a R0 resection is the second most common reason for conversion [20].

Ji et al. reported a significantly reduced blood loss using the robotic approach, in comparison with conventional laparoscopic or classical open hepatectomies (280 ml versus 350 ml versus 470 ml, respectively) [21]. The overall rate of perioperative complications after robotic hepatectomy is less than 20%, which includes liver-specific complications (e.g., bile leak, postoperative liver failure, development of ascites), those related to the operation (e.g., intra-abdominal bleeding, pleural effusion, wound infection, postoperative ileus, and organ injury), and those related to the any operation in general (e.g., postoperative venous thromboembolism, urinary tract infection, and Clostridium difficile infection) [3]. Overall, the most common complications are bile leak, development of a biloma, and intra-abdominal abscess (less than 5%). Length of hospital stay ranged from 4 to 12 days and there appeared to be variability in length of hospital stay depending on the country where the hepatectomies were performed. The shortest hospital stay was observed in the United States [3]. Ninety-day mortality rate as high as 3% was reported by Kingham et al. based on a propensity score-matched study comparing 128 patients undergoing robotic versus open hepatectomy at a single center, while other authors have reported zero mortality [22–26].

There has been limited data on long-term oncologic outcomes after robotic hepatectomy. To date, there is no evidence in the literature that documents compromise of resection margins, R0 resection rate, or worse oncologic outcomes using 5-year overall or disease-free survival with minimally invasive hepatectomy when compared to 'open' hepatectomy. Due to the relatively new developments of robotic technology for liver resection, only five series have reported postoperative follow-up longer than 9 months (range 9.6–25 months) [4, 10, 11]. With time and an increased experience in robotic hepatectomy, data on perioperative outcomes and long-term results will be available.

In conclusions, we believe that the use of robotic technology in complex hepatic resections is safe, feasible, and advantageous. This approach should be integrated into the armamentarium of modern hepatobiliary surgeons.

Compliance with ethical standards

Conflict of interest Author Sucandy, Author Gravetz, Author Ross, Author Rosemurgy declare no conflict of interest.

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