Technique and initial results of fully robotic left hepatectomy for malignant tumor: an alternative minimally invasive method to the laparoscopic approach

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Hepatic resections are widely performed for both benign and malignant liver pathology. Outcomes of hepatic resection have improved in the last decade with better understanding of liver anatomy, advancement in surgical instrumentation, improved anesthesia care, and better perioperative patient management (1). Laparoscopic liver resection has become more commonly performed since it was first described in the 1990s (2). However, there are inherent limitations of laparoscopic approach which include limited range of motion with straight instruments, a two-dimensional view, amplification of physiologic tremors, and a steep learning curve. Robotic surgical system provides a solution to these technical limitations by providing a magnified three-dimensional view, tremor filtering, articulating instruments with seven degrees of freedom, and intuitive hand control movements. The first report of robot-assisted liver resection was published in 2006 (3). Since then, robotic liver resection was developed and offered by several hepatobiliary centers around the world and it is suggested that robotic surgery can shorten the minimally invasive learning curve while achieving excellent outcomes (4-6).

In a recent retrospective study by Marino and colleagues from Italy, 35 patients who underwent fully robotic left hepatectomy for malignant tumors between 2015 and 2017 were included (7). Patients with tumor located close to main vessels or hepatic hilum, tumor extension into adjacent diaphragm, body mass index (BMI) above 35 kg/m^2, and patients with combined procedure (colectomy, biliary reconstruction, and ventral hernia) were excluded. The robotic left hepatectomy was conducted using 5-trocar technique (four robotic and one laparoscopic for assistant surgeon) following the extrahepatic Glissonian pedicle approach. The liver parenchymal transection was performed using Harmonic shears and robotic Maryland bipolar forceps.

The technique described by the authors is very similar to our technique, except we utilize vessel sealer instead of harmonic shears as the main energy source during the parenchymal transection. The reported length of hospital stay was 6.5 days, which is slightly longer when compared with our average length of stay for a robotic left hepatectomy (5 days) (8). Conversion to open approach was only necessary in two patients (5.7%), secondary to intraoperative bleeding from middle hepatic vein. This low conversion rate is supported by a previously published report by Tsung *et al.* where 93% of cases were able to be completed in a purely minimally invasive fashion when robotic system is utilized (9). The authors reported an overall perioperative morbidity rate of 17.2%. Grade III–IV Clavien-Dindo complications were seen in 8.6% of patients (bile leak, intraabdominal collections, and bowel injury). This result compares favorably with the most recent international multicenter study of 61 patients with primary hepatobiliary cancers undergoing robotic hepatectomy, where grade III–IV Clavien-Dindo complications were seen in 11.4% of the patients (8).

The authors reported no 90-day mortality with a mean follow up of 31.5 months. Three-year disease-free survival and the overall survival were 65.5% and 86%, respectively. This short-term outcome is comparable with disease-free and overall survival reported in the literatures after robotic, laparoscopic, and open hepatectomy (10). There has been no evidence to suggest worse oncologic outcomes, compromised R0 resections, or increased recurrence rates with robotic hepatectomy when compared with the laparoscopic group. This study enriches the current existing literature of robotic hepatectomy, with excellent perioperative and short-term outcomes (9-13). Established long-term oncological outcomes after robotic hepatectomy, however, are still lacking. Future multi-institutional study is necessary to further investigate and establish long-term oncological data.

There are several advantages of robotic over laparoscopic approach for hepatectomy. The robotic system facilitates portal dissection, thus easier and safer individual isolation of the inflow vascular structures, when compared to the conventional laparoscopic technique. Ability to handle vascular and biliary structures with much improved dexterity contributes to the low conversion rate of the robotic hepatectomy. The technical advantage associated with the robotic approach leads to potentially lower estimated blood loss and the need for blood transfusion (5,6,10). Control of bleeding, one of the most difficult aspects of minimally invasive hepatic resection, can be better facilitated via the robotic approach at any points during the operation, mostly due to greater degree of instrument movement and ease of suturing even in difficult to reach areas (9,14). The robotic technology also offers an enhanced technical feasibility for tumors located in difficult areas such as the posterosuperior segments, ability to perform resection with angulated transection line promoting parenchymal sparing liver surgery principal, and ability to use indocyanine green (ICG) fluorescence to help identify biliovascular structures. Lastly, biliary reconstruction such as hepaticojejunostomy during liver surgery can be completed much easier with high precision using the robotic surgical system due to enhanced dexterity. Only few surgeons have the technical ability to perform laparoscopic biliary reconstruction as perfect as open biliary reconstruction. Because of the unique advantages associated with the robotic surgery over conventional laparoscopy, further application of robotic technique in liver surgery is anticipated in the future, especially with parenchymal sparing principle.

There are several limitations of robotic approach for hepatectomy such as lack of instruments, lack of tactile feedback, and high cost of the robotic system. Cavitron ultrasonic aspirator system is only available laparoscopically (and open), but not robotically. However, as the robotic technology improves, a wider variety of device for parenchymal transection will become available. The lack of tactile feedback is still the main limitation of robotic surgical system, however, the evolution of robotic technology is continuing. Another criticism against the robotic approach is cost when compared to the conventional laparoscopy. Nowadays, however, robotic system is widely used for a wide variety of gastrointestinal and hernia operations, with many small hospitals in the US offering robotic operations. Even a much simpler operation such as inguinal hernia repair is now commonly performed robotically, despite the well-established technique and long-term outcome data of the standard laparoscopic extra/intraperitoneal repair. This rapidly expanding application of robotic surgical system mainly by open surgeons who transform to become minimally invasive surgeons sparked engineers and robotic manufacturer to innovate. Currently, Intuitive Surgical Corporation is the dominant producer of robotic surgical system (Da Vinci™) but several other systems are now in development. In the near future, industry competition will lead to cost reduction, which subsequently creates wide availability of robotic surgical system.

Currently, there is no clear standardized training for robotic liver surgery. Each individual robotic liver surgery training program relies on their own institutional policies. Formal learning curve study of robotic hepatectomy is nonexistent. Tsung *et al.* analyzed the impact of learning curve on robotic hepatectomy by comparing cases performed before January 2010 (n=13) and after January 2010 (n=44) (9). Significant differences were observed in estimated blood loss (300 *vs.* 100 mL), operative time (381 *vs.* 232 minutes), and length of hospital stay (5 *vs.* 4 days), in favor of robotic hepatectomies performed after January 2010. These data demonstrate improvements in surgical and postsurgical outcomes as experience with robotic hepatectomy increases. When compared to the laparoscopic hepatectomy which required 45–75 cases to overcome learning curve for major resection, the learning curve for robotic hepatectomy appeared to be shorter (15,16). Practice on robotic simulation machine is a recommended starting point for robotic hepatectomy training. The surgeon must have qualification in general surgery with adequate experience and full competency in open liver surgery, in addition to certain experience in laparoscopic surgery. Atlases of liver anatomy and liver surgery technique, lectures on procedures from experts in the field, detailed review of video recordings, and attending hands-on workshops formulate the initial phase of robotic hepatectomy training (17). The surgeon should first start to participate as a bedside assistant surgeon. After a certain number of operations as a bedside assistant surgeon, she/she begins to perform robotic hepatectomy as a console surgeon, starting with minor non-anatomical anterior and peripheral resections and left lateral sectionectomy. Due to the wide spectrum of extent and complexity of hepatectomies, there is still no consensus on the number of minor and major hepatectomies needed to be a recognized robotic liver surgeon. Experience of the remaining surgical team including the assistant surgeon, scrub technologist, and nursing staff is also an important part of the success.

In conclusion, robotic hepatectomy can be safely applied for the management of liver malignancies with excellent outcomes. Clear role of robotic platform in liver surgery requires a multi-institutional prospective randomized clinical trial, especially for challenging type of liver resection which requires biliary and vascular reconstruction. Lastly, standardized formal training for robotic hepatectomy is still in evolution.

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