Ruff *et al. Mini-invasive Surg* 2024;8:12
DOI: 10.20517/2574-1225.2024.39

Mini-invasive Surgery

Review

Strategies to build a robotic liver surgery program

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How to cite this article: Ruff SM, Tsung A. Strategies to build a robotic liver surgery program. *Mini-invasive Surg* 2024;8:12. https://dx.doi.org/10.20517/2574-1225.2024.39

Received: 7 May 2024 **First Decision:** 2 Jul 2024 **Revised:** 8 Jul 2024 **Accepted:** 9 Jul 2024 **Published:** 15 Jul 2024

Academic Editors: Kit-fai Lee, Giulio Belli **Copy Editor:** Pei-Yun Wang **Production Editor:** Pei-Yun Wang

Abstract
Over the past few decades, an increasing proportion of abdominal surgeries are performed through minimally invasive platforms. In contrast, adaptation of minimally invasive techniques for liver surgery has garnered slower attraction due to the complexity and associated morbidity and mortality with these operations. Compared to laparoscopy, the robotic-assisted surgical system provides a three-dimensional operative view and instruments with articulation that mimic and extend wrist movement. These elements improve operative dexterity making dissection and suturing easier. Additionally, robotic surgery improves operative ergonomics and decreases physical and mental fatigue. Studies show that the robotic platform is safe and versatile with many technical advantages for complex operations, improved short-term outcomes compared to open surgery, and comparable oncologic outcomes. As such, hepatobiliary surgeons are increasingly adapting robotic techniques in their practice. It is crucial that as more hospitals adopt this technology, patient safety monitoring and quality initiatives are maintained. Establishing a robotic liver surgery program revolves around three pillars: designing a curriculum to overcome the learning curve, building a strong clinical and administrative team, and appropriate patient selection.

Keywords: Robotic surgery, liver surgery, curriculum, learning curve

INTRODUCTION

Over the past few decades, an increasing proportion of abdominal surgeries are performed through minimally invasive platforms. In contrast, adaptation of minimally invasive techniques for liver surgery has been slower given the complexity and elevated morbidity and mortality associated with these operations. The first laparoscopic partial hepatectomy was performed in 1992 and demonstrated its safety for small tumors in the left lateral segment[1]. Since then, the use of laparoscopy for hepatectomies has steadily increased[2]. Compared to open surgery, laparoscopic hepatectomy is associated with decreased complications, lower estimated blood loss (EBL), decreased time to return of bowel function, and decreased length of stay[2-4]. Equally as important, these studies showed that there are no differences in oncologic outcomes between laparoscopic and open surgery[5-8].

However, there are some technical disadvantages with laparoscopy, especially for complex liver operations that require hilar dissection or access to tumors in difficult anatomic areas (e.g., superior-posterior tumors). Unlike laparoscopy, the robotic system provides a three-dimensional view and instruments with articulation that mimic and extend wrist movement. These elements improve operative dexterity, making dissection and suturing easier. Additionally, robotic surgery improves operative ergonomics and decreases physical and mental fatigue[9]. Studies show that similar to laparoscopy, robotic hepatectomies have improved short-term post-operative outcomes over open surgery[10-12]. Furthermore, robotic liver surgery has a lower rate of conversion to open procedures than laparoscopy[13-17]. As such, hepatobiliary surgeons are beginning to utilize robotic techniques in their practice.

A study using the National Surgical Quality Improvement Program (NSQIP) database from 2014-2020 showed that 12% of the minimally invasive hepatectomies were performed robotically[18]. While the number of robotic hepatectomies is still relatively low, the robotic approach and the number of hospitals performing robotic hepatectomies are on the rise in the United States[19]. It is our duty as clinicians to ensure that as more hospitals adopt this technology, patient safety and quality initiatives are maintained. Establishing a robotic liver surgery program revolves around three pillars: designing a curriculum to overcome the learning curve, building a strong clinical and administrative team, and appropriate patient selection.

DESIGNING A CURRICULUM AND OVERCOMING THE LEARNING CURVE

It is well established that for any new technology, there is an associated learning curve. Therefore, the success of a new robotic program is contingent on a curriculum that ensures proficiency, and maintains patient safety standards. Studies vary on the ideal number of cases required to overcome this learning curve for robotic liver surgery, with some suggesting it can be as few as 20-30 cases[20,21]. However, Krenzien *et al.* found that after adjusting for the complexity of the hepatectomy, the learning curve for robotic liver resection was higher than previously reported[22]. The discrepancy in the number of cases required to overcome the learning curve may be due to multiple factors, including surgeon experience, difficulty of the case, and participation in a training program. A single institution in Denmark reviewed its first 100 patients to undergo robotic liver surgery and showed that standardization of training led to increased proficiency and lower complication rates[21]. Rather than establishing a required number of cases for proficiency, they defined three phases of the learning curve: (1) the initial experience with simpler cases to establish a baseline skillset; (2) the second stage that pushes the surgeon's abilities with increasingly difficult cases; and (3) the final stage where the surgeon demonstrates proficiency and more nuanced moves through additional experience. With this in mind, studies have focused on curriculums designed to shorten the learning curve.

In the robotic pancreaticoduodenectomy (PD) literature, the University of Pittsburgh Medical Center found the institutional learning curve for robotic versus open PD to be similar[23]. While implementing their robotic program for PD, they monitored outcomes in groups of 20 patients to ensure that safety and quality were maintained. Furthermore, they established a five-step proficiency-based robotic training curriculum that included a simulation component consisting of 24 virtual reality modules, practice sessions with biotissue, video library review of cases, intraoperative feedback with experienced mentors, and ongoing quality assessments[24-28]. The biotissue sessions focused on complex anastomoses required for a PD and were shown to complement the virtual experience by improving metrics and decreasing errors on skill assessments. Implementation of a formal mentorship program and robotic curriculum among surgical fellows was associated with decreased learning curves and improved patient morbidity[29].

While this data is primarily in the setting of PD, the methodology of this curriculum holds true for complex operations such as a hepatectomy. Surgeons need to complete both a formal robotics curriculum and one designed specifically for liver surgery. There are clearly defined steps of a formal hepatectomy that must be demonstrated to establish competency: dissection of the hepatic hilum, hepatocaval dissection, and transection of the liver. Practice sessions with biotissue and live animal or cadaver labs should revolve around maneuvers required to complete a hepatectomy, such as obtaining proximal and distal vascular control, vessel ligation, performing a biliary-enteric anastomosis (e.g., for cases of hilar cholangiocarcinoma), parenchymal division techniques (e.g., electrocautery, vessel sealer), performing a pringle maneuver, and hilar dissection. Even for partial or parenchymal-sparing hepatectomies, this skillset will be useful and help prepare surgeons to deal with emergencies. Additionally, surgeons need the opportunity to work with different instruments in each of these scenarios so that when in the operating room they can adapt to the patient's anatomy. Animal and cadaver labs should also be used to practice trocar placement, obtain intra-abdominal exposure, and respond to emergencies (e.g., bleeding). Throughout the curriculum, surgeons must meet specific milestones prior to advancing in the program and operating on a patient.

Upfront education is critical to reducing the learning curve. Part of this curriculum requires bringing experienced robotic surgeons to the institution to lend their expertise through proctored live animal labs, cadaver labs, and live case demonstrations. As mastery is achieved, these experienced surgeons can return for additional visits to observe cases, critique technique, and offer suggestions for improved efficiency.

TEAM DYNAMICS

Equally important as the technical considerations of establishing a program is assembling a team that can overcome early obstacles and foster growth. At least two surgeons with extensive experience in open liver surgery should be committed to adopting this technology. As these surgeons become proficient, they can alternate between the robotic console and the patient's bedside to gain additional exposure. Additionally, surgeons graduating from fellowship with extensive robotic training and/or who are already established at other programs should be recruited to join the team and lend their expertise.

A dedicated team must also include the commitment and investment of the operating room staff. The same learning curve will exist for the anesthesia team, circulating nurses, scrub nurses and technologists, residents, and bedside first assistants. It is advantageous to hire and/or recruit clinical staff with robotic experience who can be an extra source of support as the program is launched. It will take time and experience to learn the instruments, robotic technology, and how to best assist the surgeon at the console. A curriculum with in-service training for all team members can shorten this learning curve. Additionally, the same team should regularly work together during early cases to provide consistency, build rapport, and eventually disseminate their expertise as mentors to the rest of the clinical staff. Most importantly, an adept clinical team acts as a safety measure to quickly resolve issues and convert to an open operation in an emergency.

Finally, given the initial investment necessary to acquire robotic consoles, instruments, and continued system maintenance, there must be support from the hospital administration[30-32]. Early on, surgeons will take longer to perform operations, which may result in a decrease in their overall productivity. Studies have attempted to define the cost-to-benefit ratio of robotic surgery, but there is significant heterogeneity in these cost calculations. These studies demonstrate that while robotics resulted in higher peri-operative expenses (e.g., longer operative times) and had a reduced reimbursement profile, the favorable clinical outcomes (e.g., shorter length of stay, decreased 90-day mortality, lower EBL, and quicker return to daily activities) may ultimately result in a savings benefit[33-35]. Furthermore, advertisement of the robotic program could potentially increase overall surgical volume in the long term, thereby providing an additional revenue stream for the hospital[36]. While not all of these patients will be candidates for robotic surgery, many will continue their care at the hospital.

PATIENT SELECTION

The third pillar of building a robotic program is patient selection. Prior to starting a robotic liver program, the hospital should already be a high-volume hepatopancreatobiliary center with an experienced multidisciplinary tumor board. This will aid in appropriately selecting patients for early cases based on anatomy and tumor location. Additionally, the clinical staff will be accustomed to caring for these patients in pre- and post-operative settings and familiar with what is needed to quickly convert to an open case in an emergency. Scoring systems, such as the IWATE criteria, can be used as a tool to guide surgeons on operative difficulty and patient selection early in the learning curve[37]. Difficult cases with aberrant anatomy, suspected vascular involvement, or that require hilar dissection should be avoided in the beginning. Furthermore, certain patient characteristics, such as a history of multiple abdominal surgeries, severe co-morbidities, or very low or high body mass index (due to the difficulty in obtaining enough working space or having adequate exposure) should be taken into account. Finally, a time limit should be set for how long the surgical team can continue before deciding to convert to an open operation. This time limit should be set for different components of the operation, ensuring forward progress is made without subjecting the patient to additional risk from extended anesthesia time, and a well-experienced open liver surgeon should be present to guide the timing of conversion to an open procedure. Quality assessment measures, including complication rate, readmission rate, EBL, operative time, conversion rate, and early mortality, should be performed at regular intervals. Case review of each component of patient care, including the pre-operative, operative, and post-operative setting should be performed to identify areas of improvement. As the surgeons and clinical team become comfortable and demonstrate competency without compromising patient safety, then case difficulty can gradually increase.

CONCLUSION

The robotic platform is safe and versatile with many technical advantages for complex operations. As more hospitals adopt robotic technology, it is critical that patient safety and quality measures are upheld. This is especially true for liver operations that already carry an elevated morbidity and mortality risk. To successfully establish and maintain a robotic liver program, it is imperative to have the support of the hospital administration and multidisciplinary team. This is accomplished through a combination of experienced hepatopancreatobiliary surgeons, recruited surgeons with robotic experience, and a clinical team dedicated to completing a standardized curriculum that includes competency assessments. Patient safety and quality measures should be evaluated at regular intervals. Finally, patients with ideal anatomy, tumor characteristics, and clinical components (e.g., body mass index, no history of previous surgery) should be selected for early cases. The difficulty level can gradually increase as surgeons overcome the learning curve and demonstrate proficiency. When employed by a dedicated team with strong mentorship, these strategies are proven to help overcome the obstacles of building a successful robotic liver program [Table 1].

Table 1. Summary of critical components to building a robotic liver surgery program

Overcoming the learning curve	● Use an established curriculum that combines simulation, biotissue practice sessions, video review, intraoperative feedback with experienced mentors, and quality assessments ● Start with simple cases and slowly increase the difficulty over time
Team dynamics	● Assemble a team with at least two surgeons with open liver experience, operating room staff (circulating nurses, scrub nurses/technologists, residents, bedside first assistants), and anesthesia ● Provide in-service trainings for staff ● The same team should work together regularly for safety measures and to quickly resolve issues ● Support of hospital administration
Patient selection	● Hospital should be a high-volume hepatopancreatobiliary center with multidisciplinary tumor board ● Difficult cases with aberrant anatomy, vascular involvement, or that require more complex components (e.g., hilar dissection) should be avoided in the beginning ● Patient factors such as history of multiple abdominal surgeries or severe co-morbidities should be taken into account early in the learning curve ● Set a time limit for difficult components of the operation to ensure forward progress ● Quality assessments should be performed at regular intervals

DECLARATIONS

Authors' contributions

Design, writing and editing of this manuscript: Ruff SM, Tsung A

Availability of data and materials

Not applicable

Financial support and sponsorship

None.

Conflicts of interest

Both authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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