



Learning curve and pitfalls in establishing a new robotic liver surgery program

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The development and adaptation of robotic-assisted surgery has provided surgeons and patients with several benefits over laparoscopic surgery. This technology allows for improved dexterity, three-dimensional binocular vision, reduced operative fatigue, improved ergonomics from the console-surgeon interface, and stabilization of tremor during surgery. The use of robotic surgery has proven to be safe and effective with comparable outcomes to the open approach for a wide range of general surgical, urologic, and gynecologic operations among others (1,2). As a natural evolution of the technique, robotic surgery has been increasingly utilized for more complex operations such as liver resection. Several case series from high-volume centers have shown that the use of robotic surgery for major liver operations can be performed safely with the potential for improved patient outcomes (1,3-8). The robotic platform has helped liver surgeons overcome many challenges in complex minimally-invasive liver operations. Specific to liver operations, the robotic platform provides surgeons with the theoretical potential to perform safer dissections and prevent massive hemorrhage by allowing the surgeon to identify major vessels more clearly and have better control during control and ligation (1). As such, there has been increasing interest in the adoption of such technology for major liver operations. This article reviews the approach to the development and implementation of a structured and successful robotic liver surgery program with a focus on the learning curve and pitfalls that may be encountered along the way.

Among one of the first published series of the use of the robotic platform for surgical oncology procedures,

King *et al.* published their experience of implementing a robotics program at The University of Pittsburgh Medical Center (UPMC) (3). In their report, the authors stressed the importance of a multidisciplinary team approach that was important for their sustained long-term success. This robotic surgery team involves the commitment and investment of not only the clinical faculty but the operating room staff and hospital administration as well. For the clinical team, dedicated surgeons, operating room nurses, scrub nurses, and anesthesiologists are required to build a robotic surgery program (3).

From a clinical and technical standpoint, there is a well-defined learning curve for surgeons who wish to adopt this new technology (2,3,6-8). This learning curve begins with mastery of the platform followed by a gradual procedural adaptation of the technology. Although reports vary on the ideal number and types of cases required to overcome this learning curve, development of these skills under the mentorship of an established robotic surgeon in an established structured program can help reduce this time (9). Perhaps equally as important, this learning curve pertains to not only the surgeon but the ancillary staff as well. It is important that the entire robotic staff are familiar with the technical aspects of performing robotic surgery. This is in line with reports from The University Medical Center of Utrecht (UMCU) who highlighted three pearls as pre-requisites for the development of the robotic hepatectomy program: the team approach/effort, availability of equipment and expertise and most importantly proctoring/mentoring (10).

In our experience, we support the approach of beginning

with case observations followed by dry and live animal lab training (10). Once mastery of the platform is achieved, we found that alternating between high-volume surgeons at the robotic console and at the patient's bedside was the best method to rapidly train surgeons in this technology. Establishing a successful robotic surgery program without the involvement of at least two surgeons willing to adopt this technology may be prohibitive. Furthermore, only surgeons with abundant experience in open liver surgery should be involved in starting a robotic liver surgery program. Similar to guidelines in laparoscopic liver surgery, we believe that novice robotic liver surgeons should begin with technically easier operations as is in line with several international guidelines (11-13). This supports the notion that “who” to operate on and “by whom” are both important factors when considering a robotic approach for liver resection.

Multiple international studies have described the learning curve in major and minor laparoscopic hepatectomies. Using the CUSUM technique, Nomi *et al.* concluded that it requires 45 major hepatectomies to overcome the initial learning curve followed by another 30 cases to master the more complex major resections (14). In another multi-institutional study by Dagher *et al.*, the authors established the existence of a learning curve for laparoscopic major hepatectomies without specifying the number of cases required to overcome it (15). Similarly, Tsung *et al.* recognized the learning curve in robotic-assisted hepatectomies. Although no particular case number was identified to overcome the learning curve, the authors did show a significantly lower estimated blood loss, decrease in operating room time and shorter length of stay in the later phases after the adoption of the robotic platform (1).

Aside from the development of technical expertise, there are many hurdles that may be encountered when establishing a robotic hepatectomy program. There has been much scrutiny regarding the cost to benefit ratio in adopting this new technology, with a major focus on the initial investing in the robotic consoles and cost of maintenance (3,9,10). Furthermore, one disadvantage of robotic surgery is the increased operating room time to perform complex liver operations (1,8,16). Several studies have attempted to comprehensively define the actual costs of robotic surgery. Between 2010 and 2014, multiple institutions analyzed cost data including instrument costs, operating room supply costs and total hospital costs and revealed that robotic hepatectomies had higher costs when

compared to their laparoscopic and open counterparts (17-20). A study by Yu *et al.* showed significantly higher medical costs associated with the robotic platform when compared to laparoscopic assisted surgery despite a longer length of stay among the laparoscopy group (Robot *vs.* Lap; $11,475 \pm 2,174$ *vs.* $6,762 \pm 1,436$ USD, $P=0.001$) (17). On the contrary, a more recent study in 2016 by Sham *et al.* showed that total hospital costs were \$4,244 less expensive in robotic surgery than in open surgery (21). Similarly, Cortolillo *et al.* showed that patients undergoing a robotic-assisted hepatectomy had lower cost of index admission among patients compared to the open approach ($\$24,983 \pm \$18,329$ *vs.* open $\$32,391 \pm \$31,983$, $P<0.001$) (6). These studies have found that though robotic resulted in higher peri-operative expenses, mostly due to longer operative times, patients undergoing robotic hepatectomy were found to have lower due to shorter length of stay and quicker return to daily activities (22). These costs when taken in totality may result in a savings benefit for a robotic approach. In addition to the actual cost of care, surgeons adopting this technology are at a potential disadvantage from a clinical productivity standpoint. Due to the longer operative times, surgeons may not be able to perform as many operations and thus may generate less work revenue. These roadblocks can be mitigated by strong institutional and administrative support in the program. One potential solution is to have the hospital and department administration provide “credits” for the robotic surgeons for the extra time required to develop and maintain a robotic surgery program.

In summary, the recipe for success in establishing a successful robotic liver surgery program is building a dedicated multidisciplinary team. Additionally, it is imperative to identify mentors or proctors to provide expertise for novice robotic surgeons to help develop the necessary skills to perform these complex operations. Lastly, it is important to have sufficient institutional support that provides surgeons with the time, staff, and resources necessary to overcome the hurdles of building a robotic liver surgery program (3,9,10).

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