Advantages of robotic over laparoscopic liver surgery—lesson learned from a high-volume medical center

Iswanto Sucandy, Andres Giovannetti

Digestive Health Institute, AdventHealth Tampa, Tampa, FL, USA

Correspondence to: Iswanto Sucandy, MD, FACS. Associate Professor of Surgery, 3000 Medical Park Drive, Suite 500, Tampa, FL 33613, USA. Email: iswanto_sucandy@yahoo.com.

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Application of minimally invasive hepatobiliary technique has been exponentially increasing worldwide since its introduction in the early 1990s. Minimally invasive techniques in liver surgery were initially applied only for minor non-anatomical resection of anteriorly and peripherally located lesions, however, it has now been adopted to major resection of >3 segments, redo resection, posterosuperior lesions resection, caudate lobe resection, and even living donor transplantation. Open and laparoscopic hepatectomy had been widely compared by many authors, including recently by the first randomized controlled clinical trial published from Oslo University Hospital (1). While providing similar oncological outcomes, laparoscopic liver resection leads to lower blood loss, less blood transfusion, less narcotic use, shorter hospital stays, and lower postoperative complications, such as wound infection, hernia formation, deep organ space infection, and cardiopulmonary complications (2,3).

Despite its obvious benefit compared to open surgery, the proportion of liver resection undertaken laparoscopically is still significantly lower compared to that of other gastrointestinal operations. Slow adoption of minimally invasive technique in liver surgery is mainly due to disadvantageous features of conventional laparoscopy. Restricted motion of rigid straight instruments, fulcrum effect, two-dimensional view, difficulty in reaching the posterosuperior segments, difficulty in suturing especially during acute hemorrhage in tight spaces, and nonergonomic nature discourage many open liver surgeons to adopt the laparoscopic approach. Compared with open liver resection, major bleeding during laparoscopic liver resection is more difficult to control due to suboptimal visualization, difficulty in promptly gaining temporary hemostasis with laparoscopic instruments, and limited degree of movement in trying to manage the bleeding. Massive bleeding despite the application of the Pringle maneuver poses a safety concern for the patient and it remains the leading cause for emergency conversion to laparotomy (4-7). Significant hemorrhage and requirement for blood transfusion have been proven to be associated with an increased risk of postoperative complications and poor long-term oncologic outcomes (8).

As more experience is gained in liver surgery since the 1970s, the clinical outcome and safety of the operation gradually improve. We now know that preserving healthy liver parenchyma is important to avoid postoperative liver insufficiency, a source of major morbidity and mortality after liver resection. As minimally invasive techniques are applied in liver surgery, the issue of preserving uninvolved liver parenchymal becomes more complex. The modern principle of parenchymal sparing liver resection is more difficult to apply using the laparoscopic technique, since the laparoscopic liver resection generally follows a straight resection line resulting in unnecessary major parenchymal extirpation, even for small or isolated liver nodules (9). Therefore, minimal access operation (laparoscopic liver resection) can result in maximally invasive parenchymal resection, exposing the patients to an increased risk of postoperative liver insufficiency. This is against the principle of modern liver surgery and must be avoided.

The advent of robotic technology presents more options to hepatobiliary surgeons undertaking liver surgery. The robotic surgical system is known to give the advantage of having a stable platform, tremor filtration, three-dimensional visualization, and superior hand dexterity, which facilitate challenging dissection/suturing in difficult to reach areas. The EndoWrist® feature helps the operating surgeon reach posterosuperior segments, facilitates safe vessel dissection at the porta hepatis, and enables curved/multiplanar parenchymal transection to maximize sparing of healthy liver parenchyma. All of these tasks can be performed by laparoscopic straight instruments, however with greater technical difficulty and often inferior precision. Lesions in posterosuperior segments and those with major vascular involvement are technically challenging when approached by conventional laparoscopy. Many surgeons even decide to undertake this type of resection via open approach. With robotic technology, this task could be approached much more easily and safer, while maintaining all the benefits of minimally invasive surgery. The luxury of having a fully integrated third arm for a dynamic retraction and manual vessel compression while trying to perform venorrhaphy or arteriorrhaphy is extremely valuable and unique to robotic surgery. In our experience, even bleeding from the main portal vein or inferior vena cava can be repaired relatively easy with the robotic system. On the contrary, achieving and maintaining a stable platform to enable rapid suturing of those bleeding vessels is often very difficult with the conventional laparoscopy, especially when an inexperienced assistant is participating in the operation.

Superior hand dexterity with the robotic technology also enables delicate biliary suturing to be accomplished, such as when the liver resection requires a biliary reconstruction in Klatskin tumor. In our center, an early stage Klatskin tumor is approached robotically. We foresee the use of robotic system for Klatskin tumor resection becomes more popular in the future. The robotic system better resembles the open approach, which presents interesting future opportunities to expand the boundaries of minimally invasive liver surgery.

Several studies have been published regarding robotic liver resection and its comparison with conventional laparoscopic technique, however, high-quality scientific evidence is nonexistent so far (10). It had been reported that the robotic approach in liver surgery produces the benefit of minimally invasive surgery when compared to open, but its superiority over conventional laparoscopy is not evident (11,12). This statement has been heavily debated among laparoscopic and robotic liver surgeons in the past few years.

Efanov *et al.* described that parenchymal sparing resection of the posterosuperior segments was undertaken more often by robotic approach, in comparison with the conventional laparoscopic technique, which commonly extends to a major resection or even a total hemihepatectomy (13,14). In patients with a cirrhotic background liver from any cause, parenchymal sparing is even more important in avoiding postoperative liver insufficiency, which can rapidly progress to irreversible liver failure. For patients with colorectal cancer with liver metastases, administration of extensive neoadjuvant chemotherapy often causes steatohepatitis and veno-occlusive liver disease, which can negatively affect liver function and its ability to recover from a major resection. Parenchymal sparing also allows for repeated liver resection(s) to be performed, should tumor recur in the liver, a phenomenon often seen in patients with colorectal liver metastasis. In the modern era of interventional radiology, where chemoembolization and Y-90 radioembolization have been widely utilized, the ability to preserve liver parenchymal is also crucial, specifically for patients who later on require a major liver resection following embolizations. Therefore, the importance of parenchymal preservation during liver resection cannot be overemphasized.

From the training perspective, laparoscopic liver surgery requires a steep learning curve with up to 60–70 resections needed for competency (15). Majority of liver surgeons are open surgeons prior to undertaking the minimally invasive approach, and many of them are facing difficulty during this transformation due to the steep learning curve. Beard *et al.* concluded that the robotic approach facilitates the reduction of the learning curve, promoting its dissemination to other surgeons (15). The last aspect in comparing the two minimally invasive approaches which often underappreciated is less surgeon fatigue with the robotic approach, especially in long operations such as hemihepatectomy or trisectionectomy (16). We believe that the introduction of the robotic system known to overcome many limitations of conventional laparoscopy will gradually show its absolute advantages and added value.

The presumed higher cost of robotic operations is one of the focus of criticism when compared with the conventional laparoscopy. The increased costs with robotic equipment and annual maintenance fee for the system cannot be ignored, however, the added value of the technology might compensate for the increase in cost. The robotic liver resection has a much lower conversion rate when compared to the laparoscopic technique. A conversion rate of 13.5% during laparoscopic liver resection has been reported by a large modern series, with majority of the intraoperative conversions were due to major hemorrhage or exsanguination (17). In our hands, the conversion rate for robotic liver resection is only 1%, with Pringle maneuver being not a routine part of our technique (18). We have not used Pringle maneuver in our last 120 robotic liver resections. Emergency conversion secondary to major bleeding leads to well-known negative effects in short-term, as well as poorer long-term oncologic outcomes due to the immunosuppressive effect of blood product administration (8). Cauchy *et al.* reported, after a propensity score matching, that the complication rate in patients who had emergency conversion was higher than in patients who did not (75% versus 47.3%, respectively, P=0.038) (17). Additionally, administration of blood transfusion to correct the acute blood loss is also costly for the health system.

The 2018 international consensus statement on robotic liver resection was held in China, which involved more than 60 clinical experts. The consensus included published articles in regards to open, laparoscopic, and robotic liver surgery. The panel of experts reported that the currently available evidence was low to very low to make definitive conclusions, as evaluated by the GRADE method (10). Furthermore, the majority of the single institutional series presented less than 70 patients, including their very early experience before the learning curve was met, even for minor liver resection. The conversion rate was 7.6% (7× higher), operative time, and estimated blood loss were also significantly higher when compared to our result (18,19). The clinical outcomes published in early series were inferior to those we observe in our high-volume robotic liver surgery center, likely caused by the early experience and being in the initial phase of the robotic learning curve. Therefore, when those results were compared against the much more mature data of laparoscopic liver resection, the robotic approach seems to produce worse perioperative outcomes (higher estimated blood loss, longer operative time), while adding no clinical benefits. As the robotic liver surgeons accumulate clinical experience, the postoperative outcomes improve rapidly, similar or better to those of laparoscopic liver resection which started a decade earlier. The use of early data of robotic liver resection for comparison with the more established technique(s) must be undertaken with a great caution. A worldwide prospective registry of robotic liver resection is needed to foster the development of the robotic technique, given the paucity of solid data and the difficulty in establishing randomized clinical trials.

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Footnote

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