Review Article

Present and future in robotic hepatectomies

Riccardo Memeo, Vincenzo Pisopiso

Department of Hepatobiliary Surgery, Ospedale Regionale "F. Miulli", Strada Provinciale Acquaviva-Santeramo, Acquaviva delle Fonti 70021, Bari, Italy

Contributions: (I) Conception and design: R Memeo; (II) Administrative support: R Memeo; (III) Provision of study materials or patients: V Pisopiso; (IV) Collection and assembly of data: R Memeo; (V) Data analysis and interpretation: R Memeo; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Riccardo Memeo, MD, PHD. Department of Hepatobiliary Surgery, Ospedale Regionale "F. Miulli", Strada Provinciale Acquaviva-Santeramo, Km 4, Acquaviva delle Fonti 70021, Bari, Italy. Email: drmemeo@yahoo.it.

Abstract: Minimally invasive surgery (MIS) is considered as gold standard in most of surgical procedure. In this field, despite an initial slow diffusion due to the cost of the robot, it represents a valid therapeutic option in gastrointestinal surgery. The aim of this paper is the role of robotic in present and future of liver surgery.

Keywords: Robotic surgery; hepatectomy; liver resection; minimally invasive surgery (MIS)

Received: 09 December 2016; Accepted: 24 April 2017; Published: 07 June 2017.
doi: 10.21037/ales.2017.05.02
View this article at: http://dx.doi.org/10.21037/ales.2017.05.02

Introduction

Minimally invasive surgery (MIS) represents a valid alternative to open techniques for selected patients and tumor location, especially in anterior segments (2 to 6) or in left lateral tumors. Even if literature demonstrates advantages as reduced blood loss, shorter postoperative stay, lower morbidity, and same oncological results compared to open surgery, major challenges remain opened. Actually, even if Louisville statement contraindicated the role of MIS for major hepatectomies and biliary resection, the last Morioka consensus in 2014 confirm the lack of evidence to generate new indications. Some progress needs to be performed, to allow a better performance of MIS. These include developing more efficient minimally invasive surgical techniques, improving patient selection for any given treatment modality, and eliminating the risk of recurrence, particularly in the liver. Future progress should develop the use of techniques involving virtual reality and robotic surgery is developing (1,2).

At the beginning of the 1990s, MIS has revolutionized surgical practice, increasing the interest in the laparoscopic approach for benign and malignant pathologies. Even if such advances were very important, laparoscopy demonstrated some disadvantages that limited its wide adoption, especially in major hepatic resection and complex cases. Limited degree of motion of the instruments, assistant depending movement of the camera, bidimensional vision and poor freedom of movement were considered as factor that limited the diffusion of laparoscopic surgery to all liver resection cases. For this reason, hepatic surgery has slowly switched to the robotic approach due to its complexity, extensive dissection, and possible future integration with new technologies. With the development of advanced laparoscopic skills, increased evidence not only demonstrates the safety and feasibility of laparoscopic hepatic surgery (1) but also pinpoints a benefit in terms of postoperative outcome and yields equivalent oncological results. With the development of robotic surgery, all limitations related to the laparoscopic approach have been overcome. A three-dimensional view and an extended degree of freedom of movement allow to perform even more complex procedures.

Recently, the development and diffusion of robotic surgery demonstrated the feasibility of living donor right hepatectomies in 13 consecutive patients in the series described by Chen *et al.* (3) with non-difference in term of postoperative patient and graft morbidity, consolidating the position of robotic surgery as solid alternative to laparoscopy in minimally invasive procedures.

State of the art

Considering literature (4-17), contraindications to robotic liver surgery include all the contraindications of open liver surgery or laparoscopic liver surgery as well as pneumoperitoneum intolerance and extensive lesions which have invaded major vascular structures or which require vascular reconstruction.

With increased experience and learning curve development, operative time ranged between 141 and 720 minutes. Tsung *et al.* (4) demonstrated reduced operative times with increased experience. Malignant diseases were present in 6% to 52% of patients, and most common malignant pathologies were hepatocellular carcinoma in 216 (37.76%) patients, followed by colorectal liver metastasis in 140 (24.5%) patients. Major resections varied from 0% in the study of Packiam to 100% in Spampinato's study, published in 2014 (10). The rate of conversion varied from 0 to 20% (42 patients out of all 551 RLS) in most cases due to difficult bleeding control or difficulties during dissection. Blood loss varied from 30 to 3,500 cc. Guilianotti *et al.* (6) showed a higher estimated blood loss (EBL) in major hepatectomies (300 *vs.* 150 mL). The report by Jin Lee *et al.* (17) had the higher complication rate (70%) with only 10% of patients who had major complications. The only death patient was reported in the series by Montalti *et al.* (18) (2.8%, 1/36 patient) compared to zero mortality in all other series. Length of stay (LOS) lasted between 2 and 26 days.

Robotic and laparoscopic liver surgery comparative studies

In the literature, there are nine series which statistically compare robotic liver resection to laparoscopic liver resection (3,4,12-15,18,19). The largest experience belongs to the group of Tsung *et al.* (4) at the University of Pittsburgh. Matched patients undergoing robotic and laparoscopic liver resections displayed no significant differences in operative and postoperative outcomes as measured by blood loss, transfusion rate, R0 negative margin rate, postoperative peak bilirubin, postoperative intensive care unit admission rate, LOS, and 90-day mortality. Patients undergoing robotic liver surgery had significantly longer operative times (median: 253 *vs.* 199 minutes) and overall room times (median: 342 *vs.* 262 minutes) as compared to their laparoscopic counterparts. However, the robotic approach allowed for an increased percentage of major hepatectomies to be performed in a purely minimally invasive fashion (81% *vs.* 7.1%, P<0.05).

In the study by Tranchart *et al.* (11), twenty-eight patients were included in each group. Despite the matching on patients, more tumors were solitary in the RLR group (P=0.02), and more were localized in the superior and posterior segments in the LLR group (P=0.003). The median duration of surgery was 210 min in the RLR group and 176 min in the LLR group (P=0.12). Conversion rate, blood loss, morbidity, and LOS were comparable in both groups.

Troisi *et al.* (12) showed a higher major hepatectomy rate in the LLR group (16.6% *vs.* 0%, P=0.011) while a parenchyma-preserving approach was favored in the RLR group (55% *vs.* 34.1%, P=0.019). The overall conversion rate was 8/40 (20%) in the RLR group and 17/223 (7.6%) in the LLR group (P=0.034). EBL mean was 330±303 and 174±133 mL for the RLR and LLR groups respectively (P=0.001), and they concluded that despite higher conversion rates and higher blood loss, robot-assisted surgery might allow for the resection of more liver lesions, especially those located in the posterior superior segments, facilitating parenchyma-saving surgery with a similar complication rate with respect to LLR.

Lee *et al.* (17) reported sixty-six LLR, and 70 RLR were performed between November 2003 and January 2015. The two groups were comparable in terms of demographic data and disease characteristics. Major hepatectomies were more frequently performed in the RLR group (20.0% versus 3.0%, P=0.002). There was no mortality. No significant differences were noted in terms of morbidity (LLR: 4.5%, RLR: 11.4%), conversion rate (LLR: 12.1%, RLR: 5.7%), EBL (both 100 mL), and median LOS (both 5 days). However, operative time was longer in the RLR group (251.5 min versus 215 min, P=0.008). No difference was noted in all perioperative outcomes between the two groups.

Montalti *et al.* (18) reported thirty-six patients who underwent robot-assisted liver resection and who were matched with 72 patients who underwent laparoscopic liver resection. No significant differences were shown in postoperative outcomes as measured by blood loss, hospital stay, R0 negative margin rate, and mortality. In addition, the overall morbidity was similar for the robotic and the laparoscopic approach respectively (34.6±33 *vs.* 18.4±11.3).

Spaminato *et al.* (10) compared 25 patients who underwent LLR with 25 patients who underwent RLR. The two groups were comparable for all baseline characteristics including type of resection (major hepatectomy) and underlying pathology. Conversion to open surgery was required in one patient in each group (4%). No difference was noted in terms of operative time, EBL, and necessity of blood transfusions. Intermittent pedicle occlusion was required only in LLR (32 % *vs.* 0, P=0.004). LOS, including time spent in intensive care unit, was similar between the two groups. No difference was noted in terms of complication rate, 90-day mortality, and readmission rate.

Future perspectives

The introduction of the indocyanine green camera on robotic system could reveal a real benefit in operative period. The possibility to recognize the anatomy of biliary tree, vascular structure, identification of vascular variations, evaluation of perfusion, identification of lymph nodes, could represent the future and the difference compared to laparoscopic and open surgery.

The fusion between three dimensional models of the liver, built up with the reconstruction made on preoperative CT scan, could be considered as an integrated system with the robot to allow an intraoperative GPS-like navigation system during surgery. The multitasking use of robot, with the possibility to superpose the 3d model with the three-dimensional view of the robot could be considered as a milestone in future for the image guided surgery. On the same way, the possibility to identify missing lesion that disappeared with chemotherapy with the superposition of the 3d model could eventually allow the resection of the suspected zone in which the lesion was present. All these concepts are basically considered as a digitalization of the operative room. All technologies are interfaced directly with the robot, as demonstrated by the TilePro function (20), who allows to simultaneously appreciate operative fields and additional sources of data, allowing to obtain a real time navigation during surgery.

Cost-effective analysis

The costs related to the use of the da Vinci™ robotic surgical system is about $1.2 million with maintenance fees of about $140,000 per year (21). In the series of Ji *et al.* (7), hospital costs of open ($10,500) and laparoscopic ($7,600) resections were lower as compared to the robotic approach ($12,000). Recently, Yu *et al.* (14) found that the robotic liver surgery cost was almost twice as high ($11,475 *vs.* $6,762, P<0.05). The reasons for higher costs are more likely multifactorial including generally longer operating room time and equipment, without significant decrease in LOS. These findings of equivalent outcomes and higher costs are similar when comparing robotic surgery to laparoscopic surgery. These findings are comparable to studies of robotic hysterectomy and prostatectomy (22,23). As more learning curves, have been achieved and further experience has been gained, it comes with no surprise that operating room times have come down, which will help offset some of these costs. Indeed, Tsung *et al.* (4) showed significantly reduced operating room times in the second part of his experience in liver resections. Further studies are required to maximize the benefits of the robotic platform considering the inherent costs.

Discussion

MIS is considerate as the gold standard in most of surgical procedure. Despite this, in hepatobiliopancreatic surgery, the diffusion is slower due to the complexity of surgery and due to the necessity of solid expertise in open surgery. For this reason, robotic liver surgery is still considered an emerging procedure, due to its technical difficulties and the unavailability of all surgical instruments, which are available for laparoscopic and open surgery. Today, laparoscopic hepatectomies are feasible and safe either for benign lesion (24) on normal liver that for malignant lesion on pathologic liver (25). Key instruments used during hepatectomies such as ultrasonic dissectors, robotic ultrasound probes and automatic staplers are appearing in robotic surgery. This will spread the use of robotic surgery even more and will consolidate the results of this review which confirms that robotic-assisted liver resection is a feasible and safe option in selected patients. No difference is shown in terms of intraoperative outcome, with no increased rate of complications and mortality. Oncological results are still a matter of debate due to the short-term follow-up for oncological patients, even if encouraging results shown on pathological findings demonstrate a non-inferiority in terms of complete resection margin and lymph nodes harvesting. Currently, most of minimally invasive hepatectomies are non-anatomical resections, and consequently the use of highly expensive surgical instruments does not seem to be justified. The true advantage of the robotic approach could be demonstrated when performing major hepatectomies requiring complex dissection (16) and reconstruction. Future technologies such as image-guided surgery (26) and fluorescence could be integrated into the robotic approach. Ideally, the limitation inherent to conventional laparoscopy could be overcome by the 360-degree mobility of robotic instruments, which could offer benefits in terms of precision and efficiency of hepatectomy, expanding the repertoire of complex minimally invasive procedures. Prospective randomized study could finally consolidate the role of robotic surgery as compared to the laparoscopic approach. It is undisputable that MIS has confirmed its role in terms of postoperative morbidity benefit (LOS, postoperative pain, morbidity, mortality, and cost-effectiveness), and considering these results, it is difficult to imagine that robotic surgery could be inferior. However, data on cost analysis are not sufficient, and the influence of the learning curve could well distort these results, which could be improved with more consistent series and with ever-increasing training so that robotic pancreatic surgeons become more skilled. Ideally, a reduction in terms of LOS with a rapid postoperative recovery could well rebalance high operative costs.

Conclusions

Robotic surgery is becoming a standard of care in most abdominal procedures. The introduction of innovative technologies in liber surgery could finally identify the role of liver robotic surgery, which up to now, apart from some rare cases, could not be defined as the standard of care.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editor (Giovanni Battista Levi Sandri) for the series "Laparoscopic Liver Surgery" published in *Annals of Laparoscopic and Endoscopic Surgery*. The article has undergone external peer review.

Conflicts of Interest: Both authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/ales.2017.05.02). The series "Laparoscopic Liver Surgery" was commissioned by the editorial office without any funding or sponsorship. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Memeo R, Sangiuolo F, De Blasi V, et al. Robotic pancreaticoduodenectomy and distal pancreatectomy: State of the art. J Visc Surg 2016;153:353-9.
2. Giulianotti PC, Coratti A, Angelini M, et al. Robotics in general surgery: personal experience in a large community hospital. Arch Surg 2003;138:777-84.
3. Tsung A, Geller DA, Sukato DC, et al. Robotic versus laparoscopic hepatectomy: a matched comparison. Ann Surg 2014;259:549-55.
4. Tsung A, Geller DA, Sukato DC, et al. Robotic versus laparoscopic hepatectomy: a matched comparison. Ann Surg 2014;259:549-55.
5. Chan OC, Tang CN, Lai EC, et al. Robotic hepatobiliary and pancreatic surgery: a cohort study. J Hepatobiliary Pancreat Sci 2011;18:471-80.
6. Giulianotti PC, Coratti A, Sbrana F, et al. Robotic liver surgery: results for 70 resections. Surgery 2011;149:29-39.
7. Ji WB, Wang HG, Zhao ZM, et al. Robotic-Assisted laparoscopic anatomic hepatectomy in China initial experience. Ann Surg 2011;253:342-8.
8. Lai EC, Chung NT, Yang GP, et al. Multimodality laparoscopic liver resection for hepatic malignancy - From conventional total laparoscopic approach to robot-assisted laparoscopic approach. Int J Surg 2011;9:324-8.
9. Lai EC, Yang GP, Tang CN. Robot-assisted laparoscopic liver resection for hepatocellular carcinoma: short-term outcome. Am J Surg 2013;205:697-702.
10. Spampinato MG, Coratti A, Bianco L, et al. Perioperative outcomes of laparoscopic and robot-assisted major hepatectomies: an Italian multi-institutional comparative

study. Surg Endosc 2014;28:2973-9.
11. Tranchart H, Ceribelli C, Ferretti S, et al. Traditional versus robot-assisted full laparoscopic liver resection: a matched-pair comparative study. World J Surg 2014;38:2904-9.
12. Troisi RI, Patriti A, Montalti R, et al. Robot assistance in liver surgery:A real advantage over a fully laparoscopic approach?Results of a comparative bi-institutional analysis. Int J Med Robot 2013;9:160-6.
13. Wu YM, Hu RH, Lai HS, et al. Robotic-assisted minimally invasive liver resection. Asian J Surg 2014;37:53-7.
14. Yu YD, Kim KH, Jung DH, et al. Robotic versus laparoscopic liver resection: A comparative study from a single center. Langenbecks Arch Surg 2014;399:1039-45.
15. Felli E, Santoro R, Colasanti MA, et al. Robotic liver surgery: preliminary experience in a tertiary hepato-biliary unit. Updates Surg 2015;67:27-32.
16. Lee JH, Han DH, Jang DS, et al. Robotic extrahepatic Glissonean pedicle approach for anatomic liver resection in the right liver: techniques and perioperative outcomes. Surg Endosc 2016;30:3882-8.
17. Lee KF, Cheung YS, Chong CC, et al. Laparoscopic and robotic hepatectomy: experience from a single centre. ANZ J Surg 2016;86:122-6.
18. Montalti R, Scuderi V, Patriti AA, et al. Robotic versus laparoscopic resections of posterosuperior segments of the liver: a propensity score-matched comparison. Surg Endosc 2016;30:1004-13.
19. Salloum C, Subar D, Memeo R, et al. Laparoscopic robotic liver surgery:the Henri Mondor initial experience of 20 cases. J Robot Surg 2014;8:119-24.
20. Guerra F, Bonapasta SA, Annecchiarico M, et al. Robot-integrated intraoperative ultrasound: Initial experience with hepatic malignancies. Minim Invasive Ther Allied Technol 2015;24:345-9.
21. Wright JD, Ananth CV, Lewin SN, et al. Robotically assisted vs laparoscopic hysterectomy among women with benign gynecologic disease. JAMA 2013;309:689-98.
22. Peppercorn PD, Reznek RH, Wilson P, et al. Demonstration of hepatic steatosis by computerized tomography in patients receiving 5-fluorouracil-based therapy for advanced colorectal cancer. Br J Cancer 1998;77:2008-11.
23. de'Angelis N, Memeo R, Calderaro J, et al. Open and laparoscopic resection of hepatocellular adenoma: trends over 23 years at a specialist hepatobiliary unit. HPB (Oxford) 2014;16:783-8.
24. Memeo R, de'Angelis N, Compagnon P, et al. Laparoscopic vs. open liver resection for hepatocellular carcinoma of cirrhotic liver: a case-control study. World J Surg 2014;38:2919-26.
25. Memeo R, Subar D, de'Angelis N, et al. A simple technique for procuring liver allografts while protecting arterial vessels. Prog Transplant 2014;24:271-2.
26. Ntourakis D, Memeo R, Soler L, et al. Augmented Reality Guidance for the Resection of Missing Colorectal Liver Metastases: An Initial Experience. World J Surg 2016;40:419-26.

doi: 10.21037/ales.2017.05.02
Cite this article as: Memeo R, Pisopiso V. Present and future in robotic hepatectomies. Ann Laparosc Endosc Surg 2017;2:98.

