International Journal of Gastrointestinal Intervention

journal homepage: www.ijgii.org

Review Article

Robotic surgery for liver, pancreas, and bile duct pathologies: A critical analysis and personal views

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ABSTRACT

At the beginning of this millennium robotic surgery was launched and quickly became accepted in many surgical specialties. Initially only resection procedures were performed with a few surgical steps made towards reconstructive elements. Robotic surgery helped to overcome disadvantages seen and experienced when performing laparoscopic procedures, mainly lack of haptic feedback, lack of 'free movement' in the abdominal cavity and inferior visualization. Since its initiation, robotic surgery was utilized more and more in complex procedures. Its use in complex liver and pancreatic surgery is still controversial as it requires a high volume center and superb training to achieve acceptable results. Robotic surgery for hepato-pancreato-biliary disease is only performed by a few centers in the United States. A team approach is mandatory and the bed side assistant is as important as the console surgeon in achieving acceptable oncological outcome. This article aims to review the most recent literature and gives some personal views into the near future with anticipated development of this exciting technology.

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Keywords: Bile duct neoplasms; Forecasting; Liver diseases; Pancreas; Robotic surgical procedures; Surgery, computer assisted

Introduction

Minimally invasive surgery has become feasible in recent years for more complex procedures. This can be attributed to better instrumentation and easier access to training courses. More sophisticated preoperative imaging has made it easier to plan resections and approach difficult target lesions. Minimally invasive surgery is definitely an acceptable alternative to open procedures for most disease sites. However, whether robotic surgery could factor into highly complex liver and pancreatic procedures from an oncological standpoint remains unclear. With three-dimensional (3D) imaging and 10-fold magnification, currently available robotic system allows for more precise dissection with less blood loss and potentially higher success rate for certain types of procedures like spleen-preserving distal pancreatectomies compared to a traditional open approach. Intrinsic disadvantages of straight laparoscopy can be overcome by the most sophisticated robotic platform currently available from Intuitive Surgery®. More platforms are currently being developed, each one targeting a specific disease site or economic niche.

Materials and Methods

We reviewed the current literature between 2010 and 2018, excluding smaller case series. A critical analysis was performed. Personal views are given.

Results

Robotic cholecystectomy (Table 1)^{1–13}

With the current platform available, two major approaches are used: single site and multi-port. We reviewed the current literature and found 2,039 cases listed in the time frame we choose. There is a big discrepancy in the overall length of stay between high volume and low volume centers. In our review, we found that low volume centers had more conservative discharge strategy with significantly longer length of stay. Operative time is infrequently reported. It is greater than one hour in most series. A single site was reported in acute cholecystectomy cases. Estimated blood loss was minimal in all series.

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Received December 27, 2018; Revised January 11, 2019; Accepted January 11, 2019

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pISSN 2636-0004 eISSN 2636-0012 <https://doi.org/10.18528/ijgii180048>

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Robotic bile duct surgery (Table 2)^{14–16}

In the current literature, we found 29 cases for review. There was only one series in the field of surgical oncology. Robotic bile duct surgery, especially when deployed for cancer in the hilum, is complex, resulting in significant morbidity with a reported blood loss of $1,360 \pm 809$ mL.¹⁶ Firefly technology in assessing bile duct anatomy and vascular supply is tremendously helpful. It is more and more utilized in complex procedures (Fig. 1).

Robotic liver surgery (Table 3)^{17–23}

Fully robotic surgery for liver pathologies is still in its infancy. More and more small series are getting published (Table 3). We reviewed a total of 153 cases in the literature. Blood loss and length of stay were similar when compared to open or straight laparoscopy. However, its operative time was significantly longer. Oncological margins did not seem to be compromised. Outcomes were also similar to laparoscopy. Smaller lesions and left lateral segmentectomies are ideal beginner cases.

Robotic pancreas surgery (Table 4)^{24–32}

Robotic pancreas surgery can be divided into two main groups: resection only and resection followed by reconstruction.

Table 1 Robotic Cholecystectomy

Study	No. of cases	OR time (min)	EBL (mL)	Length of stay (day)	Single/multiport
Grochola et al ¹ (2018)	60	85.5	5	1.9	Single
Balachandran et al ² (2017)	415	89.4	Minimal	1.9	Single
Pietrabissa et al ³ (2012)	100	71	NR	NR	Single
Lee et al ⁴ (2017)	60	86.8	NR	4.3	Single
Li et al ⁵ (2017)	78	75.7	NR	4.35	Single
Strosberg et al ⁶ (2017)	140	74.5	10	0	Single
van der Linden et al ⁷ (2016)	27	81	NR	NR	Single
Su et al ⁸ (2017)	51	71.30	NR	4.21	Single
Baek et al ⁹ (2015)	925	NR	NR	NR	Multi
Chung et al ¹⁰ (2015)	70	106	NR	1.5	Single
Ayloo and Choudhury ¹¹ (2014)	31	81.96	8.3	0.3	Single
Svoboda et al ¹² (2015)	200	69.8	NR	NR	Single
Morel et al ¹³ (2014)	82	91	NR	2.4	Single

Values are presented as number only or mean only.

OR, operating room; EBL, estimated blood loss; NR, not reported.

Table 2 Robotic Bile Duct Surgery

Study	No. of cases	OR time (min)	EBL (mL)	Length of stay (day)
Giulianotti et al ¹⁴ (2018)	14	280	135	8.4
Naitoh et al ¹⁵ (2015)	5	489	36	18
Xu et al ¹⁶ (2016)	10	703	$1,360 \pm 809$	16

Values are presented as number only, mean only, or mean $\pm$ standard deviation. OR, operating room; EBL, estimated blood loss.

We reviewed 364 cases across the whole spectrum of pancreatic surgery and found similar outcomes and similar fistula rates.

Fig. 1. Firefly exam – ‘critical view of safety’. CA, cystic artery; GB, gallbladder; CyD, cystic duct; CD, common duct.

Table 3 Robotic Liver Surgery

Study	No. of cases	OR time (min)	EBL (mL)	Length of stay (day)
Marino et al ¹⁷ (2018)	35	315	245	6.5
Magistri et al ¹⁸ (2017)	22	318	328–400	5.1–6.2
Tsung et al ¹⁹ (2014)	57	253	50–350	3–3.5
Packiam et al ²⁰ (2012)	11	175	30	4
Berber et al ²¹ (2010)	9	259	136 ± 61	NR
Croner et al ²² (2016)	10	321	306	7
Croner et al ²³ (2015)	9	312	251	6

Values are presented as number only, mean only, range, or mean $\pm$ standard deviation.

OR, operating room; EBL, estimated blood loss; NR, not reported.

Table 4 Robotic Pancreas Surgery

Study	No. of cases	OR time (min)	EBL (mL)	Length of stay (day)	Fistulas (n)
Kang et al ²⁴ (2011)	20	298	372	7.18	0
Waters et al ²⁵ (2010)	17	298	279	4	NR
Daouadi et al ²⁶ (2013)	30	293	212	6.1	14
Giulianotti et al ²⁷ (2010)	46	331	323	9.3	9
Wayne et al ²⁸ (2013)	12	298	100–350	3.9	0
Vicente et al ²⁹ (2017)	50	370	NR	17.6	10
Kim et al ³⁰ (2018)	51	335.6	NR	10.6	3
Ryan et al ³¹ (2015)	18	225	175	5	1
Kauffmann et al ³² (2016)	130	521.7 ± 98.7	$819.4–1,430.2$	NR	37

Values are presented as number only, mean only, range, or mean $\pm$ standard deviation.

OR, operating room; EBL, estimated blood loss; NR, not reported.

Discussion

As with many techniques, single site cholecystectomy has made its way into the robotic world a few years ago. The initially reported high rate of incisional site hernia when done straight laparoscopically does not seem to hold up in robotic cohorts. This might be mainly due to lessons learned from laparoscopy and improved closure techniques. Although a robotic cholecystectomy is thought to be an ideal beginner case and a case to teach residents, the surgeon controlling the arm must be aware of the significant strength these instruments translates onto the tissue or a tissue. This can result in unexpected blood loss or gallbladder rupture with bile and stone spillage.¹ Single site robotic surgery should be done only by an expert. It has a huge advantage over single site laparoscopy as it reduces surgeon's stress load.¹ When used for benign disease, chronic cholecystitis, or biliary dyskinesia, it has been proven to be an acceptable alternative to traditional cholecystectomy in terms of outcomes, although it is more expensive.²

When compared to single site laparoscopy, the robotic system developed with the Da Vinci Si/Xi® platform gives the surgeon or a surgeon a huge advantage of wristed instruments with controlled torque. This might be associated with less postoperative discomfort. When it is performed in high volume centers, it can lead to earlier discharge.

Robotic bile duct surgery is complex. Patient selection is key. It definitely has an advantage when a reconstructive element is to be considered like performing a hepaticojejunostomy given wristed instruments and micro-suturing capabilities.^{14,15} When performed for hilar cholangiocarcinoma, it can result in significant morbidity and mortality. Patient selection is a must. Short- and long-term oncological strategies also have to be considered.¹⁶

Robotic liver surgery is only performed in a few centers in the United States. This technology requires a dedicated team not only for preoperative planning, but also for safe performance of such highly complex procedures. More and more surgical teams are performing strict anatomical resections utilizing robotic platform to their advantage.¹⁷ Segments of the liver that are difficult to access with straight laparoscopy such as segment VII and segment VIII can now be safely resected with the help of magnification and wristed instruments if robotic system is available.¹⁸ Overall results show that the robotic approach does not compromise oncological margins. It is 'non-inferior' to laparoscopy or open approach, the gold standard.¹⁸ In a series of 57 patients, there was no significant difference in operative outcomes when compared to laparoscopy alone.¹⁹ Another group has demonstrated a series of 11 left lateral segmentectomies, the most straight forward liver resection, and reported inferior clinical outcomes and overall costs. They had more admissions to the surgical intensive care unit, increased rate of minor complications, and longer length of stay. This might be attributed to the utilization of a new technology and surgical teams getting familiar with perioperative algorithms rather than the robotic approach alone. When factoring in indirect costs, the robotic approach was more expensive than laparoscopy.²⁰ Overall, in all available series for review, the consensus is that robotic liver resections are feasible, non-inferior to laparoscopy or open surgery. Its benefit lays in utilizing the technology for more complex resections where laparoscopy seems to be infeasible or very difficult. Minor liver resections like left lateral segmentectomies are deemed to be good beginner cases until the steep learning curve is surpassed.^{21–23}

Pancreatic surgery can be complex. The two complex situations a pancreatic surgeon faces are spleen preservation in distal pancreatectomies and reconstruction in pancreatic head resections.

Morbidity of these procedures is quite high, especially when there is a pancreatic fistula. Spleen preservation is sometimes very difficult when using straight laparoscopy. However, it can be achieved to a higher degree using the robotic system.²⁴ Even though some series have reported an overall increase in cost, its direct costs are less, especially when performing a distal pancreatectomy. This is mainly due to a significantly shorter length of stay in the robotic group.²⁵ Pancreatic fistula, a feared complication, can be as high as 50% in some series. This might be due to the difference or a difference in parenchyma transection technique as well classification of these events.²⁵ Oncological outcomes in this short series were superior regarding lymph node yield achieved and rate of negative margins. Robotic surgery has a significantly lower conversion rate than laparoscopy. It is equivalent in terms of outcomes and safety.²⁶ The system itself with its 3D visualization and magnification allows for superior anatomical dissection around the portal/splenic vein confluence and more distally around the splenic vein itself. All small contributors to the splenic vein that could result in major bleeding can be visualized earlier and better. They can be controlled with clips, sutures, or electrocautery alone. The splenic artery is usually vessel looped at the proximal border of the pancreas. It can be traced distally very easy, controlling all small branches. Our group usually applies small cardiac clips. In 2010, one of the pioneers in robotic surgery demonstrated in his own short series of 46 patients that robotic pancreatic surgery was feasible and safe when compared to open surgery, but with added benefits of a minimally invasive approach.²⁷ When performing a Whipple (pancreaticoduodenectomy) procedure using a minimally invasive approach, the procedure itself becomes more complex as a reconstructive element is added to that. Without superb suturing technique, blood loss and fistula rate might be unacceptably high.³² This type of procedure is only performed by a handful of surgeons nationwide. Its oncological benefits need to be proven in bigger series.

Conclusion

Robotic platform provides an ideal tool for highly complex surgeries like liver resection and pancreatectomies. This is mainly due to 3D imaging and superb magnification. This technology allows for difficult reconstructions like Whipple procedures in addition to precise resections. It not only exceeds limitations seen by traditional laparoscopy, but also exceeds patient's expectations in terms of length of hospital stay and postoperative pain management. Reduction in pain is mainly due to 'controlled torque' by robotic instruments compared to 'limited control of torque' in straight laparoscopy. The future of this exciting technology lays in a happy marriage between sophisticated preoperative 3D planning of disease site and target lesion and intraoperative, superimposed imaging in order to obtain organ-sparing surgery. Added functional imaging like Firefly technology will become mainstream not only to identify critical anatomy, but also to determine residual disease not visible to the naked eye. As more robotic platforms are being developed for specific purposes, this technology will become more affordable and more widespread. Robotic surgery is here to stay. Once we overcome economic disparities and a market monopoly, it might replace traditional laparoscopy and become affordable for more institutions. More studies are needed to address its oncological outcomes but less so focusing on technical capabilities. Combined modality with intraoperative pathology mapping is an exciting outlook in the near future.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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