A single-institution study comparing robotic major hepatectomy and laparoscopic major hepatectomy for hepatocellular carcinoma in terms of short-term outcomes

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Research Article

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Abstract

Background: Nowadays, more and more major hepatectomy surgeries for hepatocellular carcinoma (HCC) are being accomplished by robots. Despite the fact that robotic surgery has the potential of overcoming some disadvantages of laparoscopic procedures, studies comparing robotic major hepatectomy with laparoscopic major hepatectomy in terms of short-term results are still scarce. This study was performed to compare robotic major hepatectomy and laparoscopic major hepatectomy regarding intraoperative and postoperative results.

Methods: Data of demographics, intraoperative and postoperative results of 131 patients undergoing robotic or laparoscopic major hepatectomy between January 2017 and March 2022 were retrieved from the medical records. Then patients undergoing robotic major hepatectomy were compared with those undergoing laparoscopic major hepatectomy in terms of demographic variables, intraoperative and postoperative results.

Results: Between January 2017 and March 2022, 44 robotic major hepatectomy and 87 laparoscopic major hepatectomy were accomplished at Department of Hepatobiliary and Pancreatic Surgery, Shenzhen People's Hospital. Firstly, patients undergoing robotic major hepatectomy were not significantly from those undergoing laparoscopic surgery in terms of age (P=0.397), gender (P=0.624), body mass index (BMI) (P=0.118), alpha-fetoprotein (AFP) (P=0.09), tumor size (P=0.176), cirrhosis (P=0.384), fatty liver (P=0.162), preoperative antiviral treatment (P=0.934), and HBV DNA (P=0.646). Secondly, it was revealed that patients undergoing robotic major hepatectomy were not significantly from those undergoing laparoscopic surgery in terms of length of hospital stay after operation (P=0.849), ICU stay (P=0.866), postoperative massive abdominal bleeding (P=1.00), portal vein thrombosis (P=1.00), abdominal infection (P=1.00), pulmonary infection (P=1.00), pulmonary embolism (P=1.00), cardiac complications (P=1.00), liver failure (P=1.00), kidney failure (P=1.00), biliary leak (P=1.00), 30-day mortality (P=1.00) and 90-day mortality (P=1.00). Thirdly, it was also demonstrated that it took significantly longer time to accomplish robotic major hepatectomy than that for laparoscopic major hepatectomy (P<0.001). Fourthly, the estimated blood loss during laparoscopic major hepatectomy was significantly more than that during robotic major hepatectomy (P=0.002).

Conclusions: Robotic major hepatectomy was as effective as laparoscopic surgery in terms of intraoperative and postoperative variables and robotic surgery took longer time than laparoscopic surgery, while robotic approach could more efficiently control intraoperative blood loss.

Background

Techniques of laparoscopy have been widely applied in resecting malignant and benign tumors of the liver[1-5]. In clinical practice, three types of laparoscopic hepatectomy including pure laparoscopic, hand-assisted laparoscopic, and hybrid approaches have been developed[6, 7]. Previously, due to the not so skilled surgical techniques, early laparoscopic resections were usually non-anatomic wedge resections of lesions located peripherally, some more recent studies have reported that anatomic major hepatectomy could also be safely accomplished by experienced surgeons [8-10]. In some previously published studies, it was reported that in comparison with open surgery, laparoscopic hepatectomy was associated with significantly less blood loss, less severe postoperative pain, shorter length of hospital stay, improved cosmesis and improved cost-effectiveness [11-15]. Additionally, some other studies had also demonstrated that for patients with hepatocellular carcinoma (HCC) or metastatic colorectal cancer (CRC), laparoscopic hepatectomy resulted in comparable R0 resection rate and 5-year overall survival[16-18].

However, for complex liver surgery, widespread application of laparoscopic surgery remains a significant challenge[19-21]. A few limitations of laparoscopic hepatectomy have been described. Firstly, unlike in open surgery, movement of laparoscopic instruments was significantly restricted (4 degrees of freedom in laparoscopic surgery and 7 degrees of freedom of the human wrist in open surgery)[22]. Secondly, satisfactory three-dimensional perspective could not be provided by laparoscopy[22]. Thirdly, during laparoscopic surgery, hand tremor would be enhanced due to long instruments and not so perfect ergonomics are commonly encountered[22]. In one study by Nguyen et al, 65% of all laparoscopic hepatic resections were left sectionectomy or non-anatomic resection, whereas only 9%, 7%, and 1% were major anatomic right, left, and extended hepatectomies, respectively[2], indicating potential difficulties encountered during laparoscopic hepatectomies. However, this situation has been remarkably improved due to the significantly improved skills of surgeons and more and more major laparoscopic hepatectomies are being accomplished each year[23].

Initially introduced in late 1980s for military purposes, robotic surgery has become a focus of research and development efforts. Theoretically, advantages of robotic surgery include the following aspects: improved dexterity and precision, higher visual magnification and remarkably decreased tremor and fatigue[22, 24]. Early experiments performed in a porcine model included cholecystectomy, choledochotomy, T-tube placement as well as repair of bile duct[25]. The first reported robotic hepatic surgery performed on a patient was accomplished by surgeons from Czech Republic[26]. Over the last decade, not only case reports and single-center series of robotic hepatic surgeries but also some large-scale studies have been published [27-30]. Despite the encouraging results reported by these studies, studies comparing robotic hepatectomy and laparoscopic hepatectomy in terms of long-term and short-term outcomes are still scarce. Furthermore, in most studies comparing robotic hepatectomy and laparoscopic hepatectomy, both minor hepatectomy and major hepatectomy had been included. Therefore, studies comparing robotic major hepatectomy and laparoscopic major hepatectomy are still needed to help surgeons choose how hepatectomy should be performed.

This study was accomplished to summarize our experience with robotic major hepatectomy for HCC at Department of Hepatobiliary and Pancreatic Surgery, Shenzhen People's Hospital since its first being applied in 2020 and compare the results with those of established laparoscopic hepatectomy. Additionally, we also reviewed the most recent studies on robotic hepatectomy.

Materials And Methods

Patients

The present study was a retrospective one in nature assessing short-term outcomes of patients with HCC who underwent robotic or laparoscopic major hepatectomy at Department of Hepatobiliary and Pancreatic Surgery, Shenzhen People's Hospital between January 2017 and March 2021. During this period, a total of 87 patients underwent laparoscopic hepatectomy and 44 received robotic hepatectomy. The following clinicopathological variables were retrieved from the medical record system of our hospital: age, gender, body mass index (BMI), alpha fetoprotein (AFP), tumor size, cirrhosis, fatty liver, preoperative antiviral treatment, HBV DNA, estimated blood loss (EBL), operation time, length of hospital stay after hepatectomy, intensive care unit (ICU) stay, postoperative complications, 30-day mortality, 90-day mortality and resection margin status. Both laparoscopic major hepatectomy and robotic major hepatectomy were accomplished as previously described[2, 31]. Major hepatectomy was defined as resection of 4 or more liver segments. Treatment strategies were made at a case discussion conference and a multidisciplinary teamwork modality was adopted. Location of lesions and overall performance status were the main factors determining range of resection. Conclusions drawn by case discussion conference were final.

Information of history, demographics, intraoperative and postoperative outcomes was obtained from patients' records. Intraoperative variables such as estimated blood loss (EBL) were identified from anesthesia and operative records. Operative time (OT) was defined as time duration between skin incision and wound closure. Postoperative ICU stay was confirmed by browsing the discharge summary. Discharge summary was also browsed to confirm postoperative complications and postoperative complications were graded using the Clavien-Dindo Classification system[32]. Major complications were defined as events that should dealt with surgery, endoscopic or radiological interventions (Clavien-Dindo classifification grade $\geq$ 3).

Ethical approval

This study was approved by the Ethical Committee, Shenzhen People's Hospital. All the patients had given his or her written informed consent. Declaration of Helsinki was adhered to during the whole process of this study[33].

Statistical analysis

Statistical Product and Service Solutions 22.0 (SPSS22.0, SPSS Inc, Chicago, IL) was used to performed statistical analyses involved in this study. Categorical variables were demonstrated as numbers and percentages while continuous variables were demonstrated as means with standard deviation. Categorical variables were analyzed using the χ^2 test, whlie continuous variables were analyzed by t test. All the statistical analyses performed in this study were two-sided in nature and P values <0.05 were considered as statistically significant.

Results

Baseline characteristics

Patients undergoing robotic major liver resection (n=44) were compared with those undergoing laparoscopic major liver resection (n=87) in terms of baseline characteristics, results of which demonstrated that two groups were not significantly different from each other regarding age (P=0.397), gender (P=0.624), body mass index (BMI) (P=0.118), alpha-fetoprotein (AFP) (P=0.09), tumor size (P=0.176), cirrhosis (P=0.384), fatty liver (P=0.162), preoperative antiviral treatment (P=0.934), and HBV DNA (P=0.646) (Table 1).

Robotic major hepatectomy Versus Laparoscopic major hepatectomy in terms of short-term outcomes

For patients undergoing robotic or laparoscopic major hepatectomy, surgery-related, postoperative and oncological results are presented in Table 2. Significant differences existed in operation time (206.78±69.19 vs 255.46±56.34 minutes, P<0.001) in favor of laparoscopic major hepatectomy. However, two groups were not significantly different from each other in terms of length of hospital stay after operation (P=0.849), ICU stay (P=0.866), postoperative massive abdominal bleeding (P=1.00), portal vein thrombosis (P=1.00), abdominal infection (P=1.00), pulmonary infection (P=1.00), pulmonary embolism (P=1.00), cardiac complications (P=1.00), liver failure (P=1.00), kidney failure (P=1.00), biliary leak (P=1.00), 30-day mortality (P=1.00) and 90-day mortality (P=1.00). Additionally, we also revealed that estimated blood loss during laparoscopic major hepatectomy was significantly more than that during robotic major hepatectomy (197.01±186.32 vs 118.86±99.09, P=0.002).

Discussion

Unlike in colorectal, gynecological and urological surgeries, laparoscopic approach has not been so widely adopted in liver surgery and most of laparoscopic liver surgeries have been performed in large tertiary care centers. Concerns about laparoscopic hepatectomy mainly lie in complex procedures, difficulties in controlling massive bleeding, and significantly steep learning curve[34, 35]. Additionally, according to a previously published study reviewing a large number of laparoscopic liver surgeries performed around the globe, majority of hepatectomy performed in a minimally invasive way were non-anatomic wedged resections for lesions located in peripheral segments[2]. And with the maturation of laparoscopic techniques, more and more major laparoscopic liver surgeries are being performed each year. More studies are needed to elucidate the roles of laparoscopic approach in liver surgery. And more and more studies were in favor of laparoscopic hepatectomy since in comparison with open surgery, laparoscopic approach was associated with much better short-term outcomes and similar long-term outcomes[11-15]. However, some disadvantages of laparoscopic surgery have also been reported. In a study by Rodrigues TFDC et al, limited image amplification, two-dimensional tremor, fulcrum effect,limited freedom of movement and low ergonomics of laparoscopic hepatectomy could be overcome by robotic approach[36].

In the present study, a matched comparison between laparoscopic major hepatectomy and robotic major hepatectomy was performed. Robotic major hepatectomy was not significantly different from laparoscopic major hepatectomy in terms of most short-term outcomes except operation time and estimated blood loos during surgery. Of these short-term outcomes, resection margin status is the most important factor indicating the quality of oncological surgery and in this study, rate of positive resection margin after robotic major hepatectomy was not significantly different from that after laparoscopic major hepatectomy, meaning that oncological quality was not compromised to achieve a technical purpose. The longer time it took to accomplish robotic major hepatectomy was in anticipation given the fact that additional time was needed to dock the robot, to install instruments and to redock or reposition instruments if change to the viewing field should be made. In the study by Allan Tsung et al, it was reported that early robotic hepatectomy took longer time than laparoscopic hepatectomy while late robotic hepatectomy was not significantly different from laparoscopic hepatectomy in terms of operation time[21]. Thus, considering these findings, we may conclude the difference in operation time is caused by learning curve and learning curve could be overcome. Similar results were reported by other studies [37, 38].

Since bleeding control is the hardest aspect of minimally invasive major liver surgeries, robotic approach may significantly reduce blood loss during major hepatectomy due to its capability of preventing bleeding of major vessels. Several characteristics of robotic surgery could prevent bleeding of major vessels. Firstly, the EndoWrist technology and three-dimensional optics of robotic system could effectively avoid injury to major vessels. Secondly, using the robotic system, surgeons could easily control extrahepatic inflow before transection while during laparoscopic hepatectomy, we prefer to use a stapler to control the portal vein. However, an ideal angle to fire the stapler is not always so easy to obtain, which may result in injury to vessels during this process. Unlike in laparoscopic hepatectomy, increased dexterity and three-dimensional viewing of robotic surgery help surgeons to perform a much safer portal vein dissection and allow surgeons to control major vessels using suture ligation rather than by stapler, which could avoid difficulties in placing staplers. Additionally, the increased movement freedom could also enable the surgeons to perform safer dissection posterior to the right hepatic vein or middle/left hepatic vein common trunk to achieve better control of extrahepatic venous outflow. Apart from better inflow and outflow control, the significantly improved magnification and viewing provided by robotic surgery enable the surgeons to more accurately identify vessels for blood control and ligation. As a matter of fact, in this study, we had demonstrated that robotic major hepatectomy was more efficiently than laparoscopic major hepatectomy in controlling bleeding.

Then we compared robotic major hepatectomy with laparoscopic major hepatectomy in terms of other short-term outcomes such as length of hospital stay after operation, ICU stay, postoperative massive abdominal bleeding, portal vein thrombosis, abdominal infection, pulmonary infection, pulmonary embolism, cardiac complications (such as heart failure, cardiac arrhythmia), liver failure, kidney failure, biliary leak, 30-day mortality and 90-day mortality , results of which revealed that two surgical approaches were not significantly different from each other regarding the aforementioned short-term variables. Thus, considering all these results of our study, we may conclude that two surgical approaches were not significantly different expect operation time and estimated blood loss and robotic hepatectomy could better control intraoperative bleeding. However, these results should be assessed by more randomized controlled studies.

Some inherent shortcomings of this study should not be neglected. Firstly, all the data involving demographics, clinicopathological variables, intraoperative and postoperative outcomes were retrospectively retrieved from patients' medical records. Therefore, these data recorded by different individuals from various departments were subject to selection biases. Secondly, a relatively small number of patients were included in this study, making a larger study involving more patients necessary to maximally minimize the underestimation regarding the significance between robotic group and laparoscopic group. Thirdly, in this study, surgical treatment was not chosen randomly. Thus, likely differences in selecting patient and/or determining surgical approaches between robotic group and laparoscopic group were not accounted for this study. However, these potential selection biases had been minimized since all the patients should at least meet indications for minimally invasive liver resection. Fourthly, each robotic liver resection at our center was performed by senior surgeons. Thus, results of our study are not likely to be applied to centers without enough experience in complex minimally invasive liver surgery since both robotic and laparoscopic major hepatectomy had better be performed at centers by experienced general surgeons. Fifthly, we did not assess whether surgical approach would affect overall survival and recurrence-free survival of HCC patients. Further studies are needed to overcome these aforementioned shortcomings. Prospectively multi-centered randomized controlled studies should be undertaken to more accurately record information of patients, select patients and record intra-operative and postoperative results.

Although it was demonstrated in our study that robotic hepatectomy could significantly reduce estimated blood loss, we did not reveal significantly shorter operation time, reduced complications and shorter hospital stay. Downsides of robotic hepatectomy are added cost and longer operation time. However, results of this study suggest that through a robotic approach, surgeons could successfully complete a major hepatectomy purely minimally invasively. In conclusion, robotic major hepatectomy has been demonstrated to own comparable feasibility and safety to laparoscopic major hepatectomy, which, however, should be further verified by more in-depth studies.

Conclusion

In conclusion, robotic major hepatectomy has been demonstrated to own comparable feasibility and safety to laparoscopic major hepatectomy, which, however, should be further verified by more in-depth studies.

Abbreviations

HCC: hepatocellular carcinoma; ASA: American Society of Anesthesiologists; BMI: body mass index; AFP: alpha-fetoprotein; ICU: intensive care unit; ICGR15: indocyanine green rate 15; CRC: colorectal cancer; EBL:

estimated blood loss; OT: operative time; SPSS22: Statistical Product and Service Solutions 22; IQR: interquartile range.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee, Shenzhen People's Hospital (NO. LL-KY-2021864).

Consent to publish

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable requests.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

LSL, YW and TLA designed this study. LSL, TCW, and JWL collected the data. TLA supervised this study. LSL, YW and TLA performed statistical analysis. LND assessed resection margin status. LSL and TLA wrote the manuscript. JLJ revised the manuscript. LSL and TLA submitted this study. All the authors read and approved the final manuscript.

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Tables

Notes: *P<0.05: statistical significance.

Table 2. Comparisons between robotic major hepatectomy and laparoscopic major hepatectomy regarding intraoperative and postoperative outcomes

Notes: *P<0.05: statistical significance.

Table 1. Comparisons between robotic major hepatectomy and laparoscopic major hepatectomy regarding baseline characteristics

Characteristics	No.	Laparoscopic (n=87)	Robotic (n=44)	χ^2/t	P Value
Age		51.49±13.27	49.82±9.06	0.85	0.397
Gender					
Male	90	61	29	0.24	0.624
Female	41	26	15		
BMI		22.28±3.61	23.29±3.12	-1.575	0.118
AFP					
□20	95	59	36	2.875	0.09
□20	36	28	8		
Tumor size					
<5cm	82	58	24	1.834	0.176
≥5cm	49	29	20		
Cirrhosis					
No	44	27	17	0.757	0.384
Yes	87	60	27		
Fatty liver					
No	111	71	40	1.954	0.162
Yes	20	16	4		
Preoperative antiviral treatment					
No	84	56	28	0.007	0.934
Yes	47	31	16		
HBV DNA					
≤10^4	81	55	26	0.211	0.646
>10^4	50	32	18		

Outcomes	**Laparoscopic (n=87)**	**Robotic (n=44)**	χ^2/t	**P**
Length of hospital stay after operation	10.25±3.51	10.21±2.19	0.190	0.849
ICU stay	2	2	0.028	0.866
Postoperative massive abdominal bleeding	0	0	0	1.00
Portal vein thrombosis	0	0	0	1.00
Abdominal infection	0	0	0	1.00
Pulmonary infection	0	0	0	1.00
Pulmonary embolism	0	0	0	1.00
Cardiac complications	0	0	0	1.00
Liver failure	0	0	0	1.00
Kidney failure	1	0	0	1.00
Biliary leak	0	0	0	1.00
30-day mortality	0	0	0	1.00
90-day mortality	0	0	0	1.00
Positive resection margin	0	0	0	1.00
Estimated blood loss	197.01±186.32	118.86±99.09	3.133	0.002
Operation time (min)	206.78±69.19	255.46±56.34	-4.036	0.000