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Robot-Assisted Versus Open Liver Resection in the Right Posterior Section

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ABSTRACT

Background: Open liver resection is the current standard of care for lesions in the right posterior liver section. The objective of this study was to determine the safety of robot-assisted liver resection for lesions located in segments 6 and 7 in comparison with open surgery.

Methods: Demographics, comorbidities, clinicopathologic characteristics, surgical treatments, and outcomes from patients who underwent open and robot-assisted liver resection at 2 centers for lesions in the right posterior section between January 2007 and June 2012 were reviewed. A 1:3 matched analysis was performed by individually matching patients in the robotic cohort to patients in the open cohort on the basis of demographics, comorbidities, performance status, tumor stage, and location.

Results: Matched patients undergoing robotic and open liver resections displayed no significant differences in postoperative outcomes as measured by blood loss, transfusion rate, hospital stay, overall complication rate (15.8% vs 13%), R0 negative margin rate, and mortality. Patients undergoing robotic liver surgery had significantly longer operative time (mean, 303 vs 233 minutes) and inflow occlusion time (mean, 75 vs 29 minutes) compared with their open counterparts.

Conclusions: Robotic and open liver resections in the right posterior section display similar safety and feasibility.

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INTRODUCTION

Laparoscopic liver resection (LLR) for lesions located in the posterior segments (PSs), namely, segments 1, 7, 8, and 4a, presents inherent technical challenges.[1] Even though appropriate adjustments and technical tricks have been described for safe and effective parenchyma-preserving surgery in PSs, operating time, blood loss, and the rate of R1 resections remain higher with respect to both LLR in the anterior segments and laparoscopic major hepatectomies.[2–4] Furthermore, studies investigating the role of laparoscopy for PS liver neoplasms revealed major hepatectomies to be the procedure of choice instead of segmentectomies and nonanatomic liver resections. [1]This appears to be in contrast to the ongoing parenchyma-preserving management of liver malignancies in both the open setting and LLR of malignancies located in the anterior segments.[2,5] Therefore, there is a general agreement to consider open liver resection (OLR) the current standard of care for lesions located in PSs, reserving LLR for surgeons with wide experience in both liver and laparoscopic surgery.[1]

Recently, robotics have been introduced in liver surgery, with the aim of overcoming some of the limitations of traditional laparoscopy, providing greater maneuverability with a set of articulated instruments and a tridimensional view.[4,6,7] Comparing LLR with robot-assisted liver resection (RALR), the latter allowed a more conservative approach, especially for lesions located in the PSs, decreasing, in turn, the rate of major hepatectomies.[8] However, the effectiveness and safety of RLR with respect to traditional open liver surgery for lesions in the PSs have not yet been investigated. The aim of this study was to pinpoint the early outcomes of open and robotic liver resections in a subgroup of patients with liver lesions in the right posterior section, with special reference to lesions posterior to the right hepatic vein or superior to the right portal vein, excluding resections of the anterior aspect of segment 6, which are considered straightforward laparoscopically. To address this issue, we retrospectively analyzed the differences in demographics, technical details, and outcomes of open and robotic liver resections for lesions in the right posterior section at 2 institutions, each with specific experience in open and minimally invasive liver surgery.

METHODS

Population Under Study

Data were retrieved from the databases of 2 Italian departments of surgery. The first group was a series of 19 consecutive patients who underwent RALR in segments 6 and 7 from January 2007 to June 2012 at a referral center for minimally invasive surgery (Division of General, Minimally Invasive and Robotic Surgery, Spoleto, Italy). All of these patients underwent macroscopic curative liver resection for primary or secondary liver tumors and benign conditions with a robot-assisted laparoscopic technique and were prospectively reviewed through a maintained nonselective liver surgery database. Patients with lesions at the anterior border of segment 6 were excluded from analysis.

Data for the second group were retrieved from the liver surgery database at a high-volume hepatobiliary center, the Hepatobiliary Unit, Department of Surgery, San Raffaele Scientific Institute (Milan, Italy). Between January 2004 and December 2012, 1416 consecutive liver resections were prospectively collected in a single database containing clinical, surgical, pathologic, and follow-up information for patients submitted to OLR. A laparoscopic series was not considered, because of the purpose of the study. As first selection, the group of patients who underwent macroscopic curative OLR in segments 6 and 7 from January 2007 to June 2012 was extrapolated to avoid bias due to the learning curve and the implementation of surgical techniques. On the basis of indications given in the operative report, patients with lesions at the anterior border of segment 6 were excluded. The period of recruitment was considered ended in June 2012, enabling at least 6 months of follow-up for each enrolled patients. Only those patients with completed perioperative data available at the end of recruitment were selected for comparison. A total of 102 patients met these criteria and formed the basis of the control group. As further assessment, a subgroup of patients was extrapolated among the control group according to an individually matched case-control design with RALR cases. The OLR cases were individually selected as accurately as possible to exclude patients with extrahepatic disease (29 cases), patients in whom LLR was attempted (2 cases), and patients who underwent concomitant radiofrequency ablation (2 cases). Ultimately, a total of 69 patients were selected, with a ratio between the numbers of the 2 groups of 1:3.6. Clinical and pathologic characteristics, postoperative outcomes, hospital course, and postoperative morbidity and mortality were compared between the RALR and OLR groups.

Demographic data, surgical procedures, postoperative course, and outpatient follow-up were reviewed. The following data were collected prospectively: age, sex, preoperative workup, type and location of the liver nodule, size, type of procedure, duration of surgery, blood loss, intraoperative complications, pathologic findings, postoperative complications, and hospital stay.

Operative time was calculated as the time between laparotomy and skin suture for OLR and the time between pneumoperitoneum induction and port-site closure for RALR. Intraoperative blood loss was measured by subtraction.

All patients entered a protocol of follow-up and underwent periodic physical, biochemical, and radiologic examinations. The terminology for liver anatomy and resection was based on the Brisbane classification.[9] Complications were classified according to the Clavien-Dindo classification in both databases.[10] Prior consent was obtained, and full treatment options were offered to all patients treated.

Surgical Procedure

Surgical technique for robotic liver resection. All procedures were carried out using the da Vinci S Surgical System (Intuitive Surgical Systems, Sunnyvale, California), and ultrasound exploration was completed with an Aloka Prosound Alpha 7 (Aloka, Tokyo, Japan). For lesions in segments 6 and 7, the patient was rotated on the left flank to facilitate liver mobilization and inferior vena cava dissection. After 12 mm Hg pneumoperitoneum was induced with a Veress needle, the camera port and the left robotic trocars were placed at the level of the right costal margin, whereas the right robotic trocar was inserted in the intercostal space between the 10th and 11th ribs along the scapular line, as previously described.[4] Two accessory trocars can be placed along the midline and the anterior axillary line for suction and retraction. To control liver inflow, an extracorporeal tourniquet was used to encircle the liver pedicle and carry out the Pringle maneuver in an intermittent fashion (10 minutes of ischemia, 5 minutes of reperfusion).[11] Moreover, a single dose of a medium-half-life steroid drug (methylprednisolone 500 mg; Solu-Medrol, Pfizer, Rome, Italy) was administered at the induction of anesthesia to reduce the oxidative parenchymal damage induced by the intermittent ischemia-reperfusion vascular control. Parenchyma was usually transected with a harmonic scalpel for straight-line resections. The

Kelly-clamp crushing technique using EndoWrist bipolar Precise forceps (Intuitive Surgical Systems) was preferred for curved and angulated section lines and tumor dissection close to major liver vessels. Hemostasis of small vessels was obtained with monopolar or bipolar cautery. To secure larger vessels on the transection line, we used Hem-o-lock clips (TFX Medical Ltd, Durham, North Carolina) or ligatures with Vicryl or Prolene. The hepatic veins were usually divided with the laparoscopic linear stapler (Endo GIA; Ethicon Endo-Surgery, Cincinnati, Ohio) or sutured. A suction drainage was always left in place. The specimen was generally extracted through the umbilical port, as previously described.[12]

Surgical technique for OLR. Abdominal incision consisted of a right angle laparotomy in the right upper quadrant, allowing favorable access to the posterior liver segments. Intraoperative ultrasonography was used to plan the parenchymal transection, and the resection line was outlined on the liver surface with electrocautery marks. Liver resection was performed using the SonoSurg System (Olympus, Tokyo, Japan), which integrates an ultrasonic dissector and an ultrasonic coagulating cutter. The ultrasonic dissector was used to fracture hepatocytes along the proposed line of division, leaving intact the crossing arteries, veins, and bile ducts. Thus, intraparenchymal vascular anatomy could be easily defined, and a decision on hemostatic technique could be made on the basis of vessel size. Millimetric structures were effectively coagulated using the bipolar forceps, whereas larger vessels and biliary branches were sealed with titanium clips or sectioned between ligatures. The few larger vessels and portal triads were divided using vascular staplers (ETS-Flex; Ethicon Endo-Surgery). Considering the usual ineffectiveness of the ultrasonic dissector in cases of cirrhotic liver, the ultrasonic coagulating cutter was adopted in these cases as able to effectively transect fibrotic parenchyma. An argon beam coagulator was used to refine unsatisfactory hemostasis, possibly in addition to the application of hemostatic matrixes on the transection surface. A single flat Jackson-Pratt drain was placed in the posterior aspect of the resection bed. As a rule, the hepatic pedicle was encircled by a tourniquet before transection, allowing the Pringle maneuver to be performed as needed in an intermittent fashion (10 minutes of ischemia, 5 minutes of reperfusion). Moreover, a single dose of a medium-half-life steroid drug (methylprednisolone 500 mg; Solu-Medrol) was administered at the induction of anesthesia to reduce the oxidative parenchymal damage induced by the intermittent ischemia-reperfusion vascular control.

In both groups, a soft diet was started the day after surgery.

Table 1.
Patient Demographics, Indications for Liver Surgery, and Clinical Characteristics

Variable	Robotic (n = 19)	Open (n = 69)	*P*
Demographics			
Age, y	62.6 ± 10.4	63.2 ± 11.5	.40
Men	12 (63.2%)	42 (60.9%)	.30
BMI, kg/m^2	28.6 ± 4.6	24.6 ± 4.3	.60
ASA class 3	4 (21.1%)	6 (10.7%)	.10
Indications for surgery			.002
Colorectal liver metastases	13 (68.4%)	46 (67.6%)	
HCC	1 (5.3%)	15 (22.1%)	
Benign	1 (5.3%)	7 (10.3%)	
Cholangiocarcinoma	1 (5.3%)	0	
Others	3 (15.8%)	0	
Nodule number	1.7 ± 1.3	1.3 ± 0.6	.10
Nodule dimension, cm	4.1 ± 2.6	4.1 ± 3	.60
Nodule site			.02
Segment 6	3 (15.8%)	21 (30.4%)	
Segment 7	11 (57.9%)	16 (23.2%)	
Segments 6–7	5 (26.3%)	27 (39.1%)	
Previous abdominal surgery	5 (26.3%)	46 (66.7%)	.002
Neoadjuvant chemotherapy	8 (42.1%)	37 (60.7%)	.10

Data are expressed as mean ± SD or as number (percentage).
Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; HCC, hepatocellular carcinoma.

Statistical Analysis

Continuous data are reported as mean ± SD (range) and were compared by using the 2-sided Student *t* test. Comparisons between groups for categorical variables were performed using the χ^2 test with Yates's correction or the Fisher exact test as appropriate. Statistical significance was set at $P < .05$. Statistical analysis was performed with SPSS Statistics version 19.0 (IBM, Armonk, New York).

RESULTS

Patient demographics, indications for liver surgery, and preoperative data are shown in **Table 1**. Patient demographics were not significantly different between the 2 groups. The comorbidity rate was similar as well, as demonstrated by the same patient stratification on the basis of American Society of Anesthesiologists score. The rate of previous abdominal surgery was signifi-

Table 2.
Types of Liver Resections in Both Groups

Type of Resection	Robotic (n = 19)	Open (n = 69)	P
Subsegmentectomy	5 (26%)	8 (11.6%)	
Multiple subsegmentectomies	2 (10.5%)	1 (1.4%)	
Segmentectomy	8 (42.1%)	31 (44.9%)	
Right posterior sectionectomy	3 (15.8%)	29 (42%)	
Pericystectomy	1 (5.3%)	0	
			.50

Table 3.
Perioperative Details

Variable	Robotic (n = 19)	Open (n = 69)	P
Operating time, min	303 ± 132.3	233.9 ± 81	.002
Pringle maneuver	12 (63.2%)	22 (37.3%)	.10
Pringle maneuver, min	75.4 ± 43.2	29 ± 14.8	.004
Blood loss, mL	376.3 ± 410	457.5 ± 365.5	.40
Intraoperative transfusions	6 (31.6%)	9 (15%)	.50
Postoperative transfusions	2 (10.5%)	4 (7%)	.60
Postoperative stay, d	6.7 ± 3	7.9 ± 4.4	.60

Data are expressed as mean ± SD or as number (percentage).

cantly higher in the OLR group (26.3% vs 66.7%). Indications for surgery were similar, except for benign diseases and hepatocellular carcinoma, operated on at a higher rate in the OLR group. Resection types are shown in **Table 2**. No major hepatectomies were performed in either group. Operative characteristics are shown in **Table 3**. RALR was characterized by a more liberal use of the Pringle maneuver and longer operative times. Even though a trend toward a shorter hospitalization was observed in the RALR group (6.7 vs 7.9 days), blood loss and intra- and postoperative transfusions did not differ between groups.

Overall morbidity and mortality rates were similar, at 15.8% and 0% and 13% and 0%, in the RALR and OLR groups, respectively **(Table 4)**. In the RALR group, a significantly higher rate of chest complications was registered, including both pleural effusion and pneumonia. In the OLR group, sepsis was the main medical complication, with a rate significantly higher with respect to the RALR group (P = .002).

Table 4.
Overall Specific Morbidity and Mortality According to Clavien-Dindo Classification

Complication	Robotic (n = 19)	Open (n = 69)	P
Surgical complications	3 (15.8%)	9 (13%)	.70
Liver failure	0	2 (2.8%)	.10
Biliary leak	2 (10.5%)	1 (1.4%)	.06
Ascites	0	1 (1.4%)	.50
Postoperative hemorrhage	2 (10.5%)	5 (7.2%)	.60
Medical complications	3 (15.8%)	7 (10.1%)	.50
Pneumonia	3 (15.8%)	0	.002
Fever (Positive blood culture)	0	5 (7.2%)	.002
Pleural effusion	2 (10.5%)	0	.006
Other	2 (10.5%)	2 (2.8%)	0
Minor (grade 1)	4 (21.1%)	13 (18.8%)	.80
Major (grades 2–4)	1 (5.3%)	1 (1.4%)	

According to the Clavien-Dindo classification, major (grades 2–4) complications were not significantly different between the 2 groups (5.3% vs 1.4%; P = .80).

Histologic Assessment

The 2 groups had similar total lesion numbers and mean nodule dimensions. In malignancies, tumor-free margin rates were similar in both groups (10.5% and 9% R1 resections, respectively, for RALR and OLR, $P > .05$).

DISCUSSION

To date, LLR is considered a safe option for the treatment of primary and secondary tumors of the liver as well as of benign conditions. However, laparoscopy is far from optimal for lesions located in the PSs. When faced with posterior and deeply located lesions, laparoscopy is associated with a trend toward an increased rate of major hepatectomies, with the sacrifice of a large amount of healthy parenchyma. In a series reported by Castaing et al[13] comparing 2 matched groups of 60 patients, in the LLR group, the rate of right hepatectomies was 35% higher than in the OLR group (20 vs 7). In a multicenter study by Nguyen et al,[14] the rate of right hepatectomies was reported to be 28.4%. Similarly, in a series of LLRs for right posterior lesions presented by Cho et al,[15] 5 of 40 patients underwent right hepatectomies (12.5%). These data are in net contrast with the actual trend of parenchymal preservation for both primary and secondary liver tumors.[5] Even when laparoscopic resections are performed in PSs with attempted preservation of the parenchyma, they are poorly effective and generally associated with higher blood loss compared with resections of the anterior segments.[15,16]

Recently, robotic surgical systems have been introduced to improve the surgical skills needed during demanding surgical procedures, including laparoscopic liver and biliary surgery.[7,17,18] With regard to liver surgery, there is some evidence that the da Vinci Surgical System may facilitate biliary reconstruction, major hepatectomy, and resection of PSs and reduce the conversion rate.[4,19] Recently, a comparative 2-institution study showed the possibility offered by robotic assistance in managing patients with larger numbers of lesions and limiting the rate of major hepatectomy at the same time. The numbers of subsegmentectomies and mixed resections were significantly higher in the robotic group with respect to the laparoscopic group (37% vs 16.1%), especially for lesions located in PSs (55% vs 34.1%, $P = .019$). On the basis of this study, the articulated robotic instruments may reproduce the Kelly-clamp crushing technique, and the wrist-like movements allow challenging resections, even in PSs.[8] Therefore, even if robotics seem to overcome some of the limitations of laparoscopy to approach PSs, there is no evidence for the effectiveness of robotics with respect to open surgery that is widely accepted as the standard of care for patients with liver nodules in the PSs.[1]

To the best of our knowledge, this is the first time a study has addressed this issue. Therefore, results from our study could elucidate whether robotics might offer early outcomes comparable with those attained by open surgery for patients eligible for liver resection in the PSs.

The most notable finding of the present study was that OLR and RALR are equally safe and feasible, with minimal blood loss and acceptable morbidity that contributed to short patient hospitalizations in both groups. Differences among patients affected by hepatocellular carcinoma and previous abdominal surgical procedures can be related to effects of center volume and/or referral patterns, but we believe that these data do not affect the peri- and postoperative outcome measures. Types of resections were comparable between the 2 groups in terms of equal numbers, sizes, and locations of liver lesions, although a trend toward a larger number of right posterior sectionectomies was seen in the OLR group. Notwithstanding the similar distribution of type of resections, operating time was longer and the Pringle maneuver was more extensively used in the RALR group. Aspects of robotic operative techniques could explain these results. In the RALR group, liver resection was carried out using articulated robotic instruments, reproducing the Kelly-clamp crushing technique under intermittent inflow occlusions.[20] This technique was initially developed to obviate the lack of specifically designed tools for parenchymal transection. Because of extreme flexibility and versatility of the articulated bipolar forceps, the Kelly-clamp crushing technique became the standard practice for liver resection, allowing challenging resections in PSs and dissections close to the main liver vessels.[4] It is likely that, with the introduction of articulated robotic devices specifically designed for liver transection, blood loss and transection time could be further reduced.

Even with a substantial difference in technical features, there were no differences between the RALR and OLR groups in terms of overall postoperative morbidity. These data are particularly interesting considering the reported higher blood loss and the scarce performance of laparoscopic surgery to approach the PSs.[15] The higher rate of thoracic medical complications in the RALR group could be related to the prolonged left lateral decubitus position, with consequent difficulties in lung ventilation. The higher rate of biliary leaks in the RALR group could be related to the presence in this group of patients with hydatid cysts, which are traditionally associated with a high rate of postoperative biliary fistula.[21] Lengths of hospital stay were in turn comparable between the 2 groups of patients.

Another factor that might influence the length of stay was the routine application of a fast-track protocol in the OLR group. This observation deserves closer consideration. Robotic surgery is not cost effective if not coupled with perioperative care aimed at fast recovery. The implementation of fast-track care has been demonstrated to significantly reduce hospital stays in patients who undergo laparoscopic colectomy, and if an open colectomy is undertaken, it is preferentially done coupled with fast-track care.[22] In our study, there was consistent evidence that this role could also translate to liver resections in the PSs. Thus, future studies evaluating the cost-effectiveness of robotic liver resection on a prospective basis should also investigate the effects of postoperative fast-track care on total hospital costs. The comparable results of RALR and OLR support the need for better refined studies on specific issues, other than cost-effectiveness. Effects of magnification and 3-dimensional views on specific complications (ie, biliary fistula), outcomes of robotic resections in specific subgroup of patients (ie, those with cirrhosis), and postoperative quality of life need to be better clarified.

CONCLUSIONS

RALR is a safe and feasible option for selective lesions in the right posterior section. The perioperative outcome profiles are comparable with those of OLR. Although short-term postoperative outcomes of RALR for segments 6 and 7 are encouraging, further analysis is needed to determine the oncologic soundness of a robotic approach for malignant tumors. In addition, a randomized controlled study is needed to further demonstrate the efficacy and cost-effectiveness of RALR in the PSs compared with open and laparoscopic hepatectomies. Data from this study could be used as a baseline for future prospective studies investigating specific issues in liver resection in the PSs.

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