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Early outcomes of single-port robotic left lateral sectionectomy in patients with hepatic tumor

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Purpose: Laparoscopic left lateral sectionectomy (L-LLS) stands as a cornerstone procedure in hepatobiliary minimal surgery, frequently employed for various benign and malignant liver lesions. This study aimed to analyze the peri- and postoperative surgical outcomes of single-port robotic left lateral sectionectomy (SPR-LLS) *vs.* those of L-LLS in patients with hepatic tumors.
Methods: From January 2020 through June 2023, 12 patients underwent SPR-LLS. During the same period, 30 L-LLS procedures were performed. In total, 12 patients in the robotic group and 24 patients in the laparoscopic group were matched.
Results: When the SPR-LLS and L-LLS groups were compared, the operation time was longer in the SPR-LLS group with less blood loss and shorter hospital stay. Postoperative complications were observed in 3 patients in the L-LLS group (12.5%) and 1 patient in the SPR-LLS group (8.3%).
Conclusion: SPR-LLS using the da Vinci SP system was comparable to laparoscopic LLS in terms of surgical outcomes. SPR-LLS was associated with lower blood loss and less postoperative length of stay compared to L-LLS. These findings suggest that left lateral sectionectomy is technically feasible and safe with the da Vinci SP system in select patients.
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Key Words: Hepatocellular carcinoma, Laparoscopy, Liver disease, Minimally invasive surgical procedures, Robotic surgical procedures

INTRODUCTION

Hepatic surgery has witnessed remarkable advancements in recent years driven by the continual pursuit of minimally invasive techniques that optimize patient outcomes and reduce postoperative morbidity [1-4]. Among these innovations, robot-assisted surgery has revolutionized the landscape of hepatic resection. Robotic platforms offer enhanced dexterity, 3-dimensional (3D) visualization, and improved ergonomics, all of which can potentially mitigate the challenges associated with complex liver surgery [5,6].

Laparoscopic left lateral sectionectomy (L-LLS) is a cornerstone procedure in minimal hepatobiliary surgery that is frequently employed for various benign and malignant liver lesions [7,8]. Traditional L-LLS, marked by smaller incisions and reduced trauma, has steadily gained acceptance as a safe and effective approach for this procedure. The advantages of robotic platforms for left lateral sectionectomy (LLS) remain

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controversial. Several retrospective studies with small sample sizes have compared robotic LLS (R-LLS) and L-LLS. The results of these studies are mixed, with no clear advantages associated with either approach [9-11]. We present the first case of robotic liver resection using the da Vinci SP robotic platform and demonstrate the technical feasibility of this platform as done previously [12].

Although both laparoscopic and robotic approaches to LLS have demonstrated their merits, rigorous comparative analyses are essential to discern their relative advantages in surgical outcomes and perioperative safety.

Therefore, this study aimed to contribute to the existing body of knowledge by conducting a comprehensive evaluation of the surgical outcomes in patients who underwent LLS using either a single-port robotic or laparoscopic technique.

To minimize selection bias and potential confounding factors inherent to retrospective analyses, we used propensity score matching (PSM); this allowed the creation of matched cohorts of patients with similar baseline characteristics, facilitating a more robust and unbiased comparison between the 2 surgical approaches. By meticulously examining perioperative variables and postoperative complications, we sought to determine whether single-port robotic LLS (SPR-LLS) or L-LLS offers superior clinical outcomes and patient satisfaction.

METHODS

Ethics statement

This study protocol was approved by the Institutional Review Board of the Korea University Guro Hospital (No. 2021GR0559) and informed consent was obtained from all patients.

Patient selection

Between January 2020 and June 2023, 12 patients underwent SPR-LLS and 30 underwent L-LLS.

There are no exclusion criteria used differentially when applying laparoscopic and robotic procedures. Patients with a Child-Turcotte-Pugh score of C and cases suspected of major vessel invasion such as the left hepatic vein were equally excluded from surgery. In total, 12 patients in the SPR-LLS group were matched in a 1:2 ratio with 24 patients in the L-LLS group using PSM. The variables used in PSM matching were age, body weight, body mass index, indocyanine green retention rate at 15 minutes, total bilirubin level, prothrombin time, platelet count, tumor size, and underlying liver cirrhosis status. The same surgeon performed all laparoscopic and robotic surgeries. Estimated blood loss was calculated using the hemoglobin dilution method. All medical data were analyzed retrospectively.

Surgical procedures

Laparoscopic left lateral sectionectomy

The Pringle maneuver was used during parenchymal transection, when necessary. The livers were transected using an alternating combination of a laparoscopic ultrasonic aspirator (Cavitron Ultrasonic Surgical Aspirator [CUSA] Excel, Integra LifeSciences) and THUNDERBEAT (Olympus). The hepatic parenchyma was divided along the right side of the falciform ligament; the pedicles to segment IV were also divided. Small branches of the hepatic vein were controlled using endoclips. After the initial parenchymal dissection on the lateral side of the liver, the right anterior Glissonian pedicle was transected using an endoscopic linear stapler (Endo GIA Curved Tip Reload with Tri-Staple with iDrive Ultra Powered Stapling System, Medtronic). The specimen was wrapped in an endo bag and extracted through a separate Pfannenstiel incision in the pelvic region. After careful hemostasis, fibrin glue and hemostatic materials were applied to the liver cut surface. A drain was inserted, and the wound was closed layer by layer.

Single-port robotic left lateral sectionectomy

A vertical incision of 3.0–3.5 cm was made at the umbilicus. A uniport device (da Vinci SP Access Port kit, Intuitive Surgical) was applied for the use of suction and endosurgical staplers. The da Vinci single 2.5cm trocar was then inserted and connected to an insufflator. After changing the patient's position to the reverse Trendelenburg position with the right side up, the trocar was docked to the da Vinci SP patient-side cart arm. A camera was inserted in the lower middle of the hole. The fenestrated bipolar forceps were placed in the left hole (arm 1), Cadiere forceps in the upper-middle hole (arm 2), and monopolar forceps in the right hole (arm 3). After docking and setting up the instrument, the round ligament was separated from the abdominal wall, and the left triangular ligament was dissected to allow the left liver to move. Superolateral traction of the detached round ligament was performed using arm 2. The hepatic parenchyma was divided along the right side of the falciform, and the pedicles of segment IV were divided using endowrist monopolar forceps (arm 3) and bipolar forceps (arm 1) using the Kelly clamp crushing method. If necessary, the Pringle maneuver was used during parenchymal transection by adopting a long, barrel-like object made of transparent silicone. Larger structures were secured using Hem-o-lok clips. The portal pedicles and major hepatic veins were divided using an endoscopic linear stapler (Endo GIA Curved Tip Reload with Tri-Staple with iDrive Ultra Powered Stapling System). After the resected specimen was completely divided, it was inserted into an endobag (Supplementary Video). After careful hemostasis, fibrin glue and hemostatic materials were applied to the surface of the dissected livers. After checking for hemostasis and bile

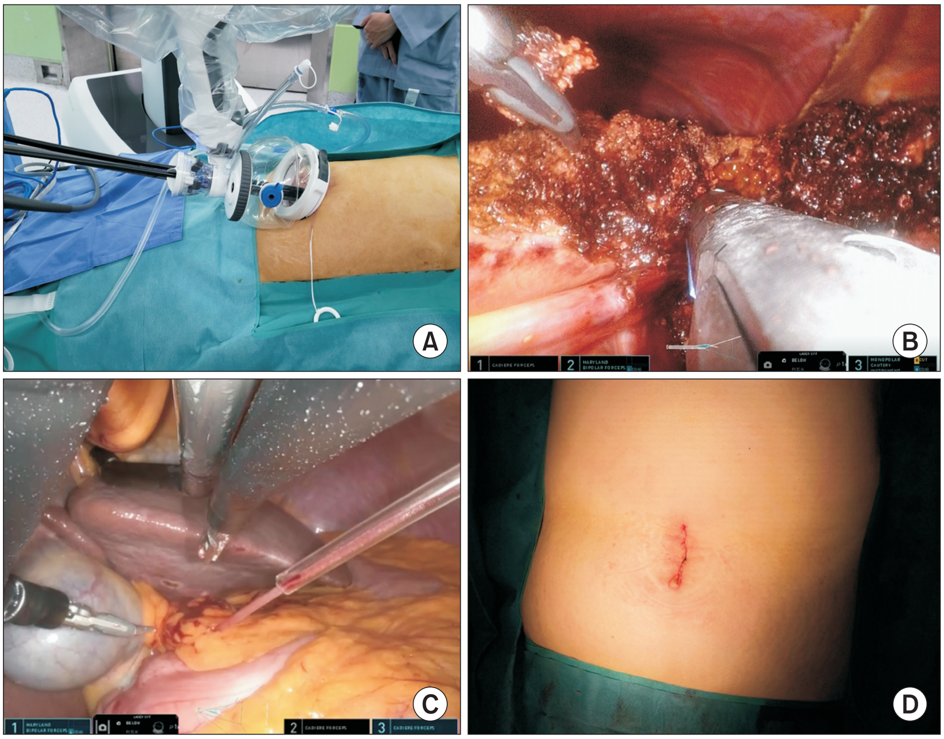

Fig. 1. Intraoperative procedure of the robotic SP left lateral sectionectomy. (A) External view of the docked da Vinci SP system (Intuitive Surgical). (B) Portal pedicles were divided using an endoscopic linear stapler. (C) View of performing Pringle maneuver using transparent silicone tube. (D) A 3-cm skin incision at the umbilicus.

leakage, instruments were withdrawn, the patient's cart arm was unlocked, and the specimen was pulled out using a single-site port and a uniport device (Fig. 1).

Statistical analysis

Data with a normal distribution are reported as means with standard deviation. Variables not fitting a normal distribution were presented as IQR (interquartile range). Continuous variables were compared using the Student t-test if normally distributed; otherwise, the Mann-Whitney U-test was used.

Categorical variables were compared using the chi-square test. Overall survival and disease-free survival rates were estimated using the Kaplan-Meier method and compared using log-rank tests. Data were considered statistically significant at $P < 0.05$. Multivariate models were manually constructed using a forward strategy. Statistical analysis was conducted using IBM SPSS Statistics ver. 21.0 (IBM Corp.).

RESULTS

Patient demographics and characteristics

A total of 36 patients who underwent SPR-LLS or L-LLS were included in this study. Of these, 12 were enrolled in the SPR-LLS group (mean age, 59.6 years; male, 7 [58.3%]), and 24 were in the L-LLS group (mean age, 61.0 years; male, 15 [62.5%]). Patients in both groups had comparable characteristic features, and there were no significant differences between the robotic and laparoscopic groups in age, sex, previous abdominal surgery history, body mass index, laboratory findings associated with the liver, or American Society of Anesthesiologists classification. Details of patient characteristics are shown in Table 1.

Peri- and postoperative outcomes

No patients required conversion to open surgery in either of the groups. The peri- and postoperative outcomes are summarized in Table 2.

Twelve (50.0%) and 9 patients (75.0%) received the Pringle maneuver in the L-LLS and SPR-LLS groups, respectively. Two patients in the L-LLS group received blood transfusions due to excessive blood loss, cirrhosis, or poor coagulation function. Postoperative complications were observed in 3 patients in the L-LLS group (12.5%) and in 1 in the RPS-LLS group (8.3%). No major complications (Clavein-Dindo classification, ≥III) or death occurred among the patients. Twenty-one patients in the L-LLS group (87.5%) and 11 in the SPR-LLS group (91.7%) had hepatocellular carcinoma.

Compared with patients in the L-LLS group, SPR-LLS group patients had longer operative time (151.8 minutes *vs.* 115.1 minutes, $P = 0.004$), less estimated blood loss (121.2 mL *vs.* 175.4 mL, $P = 0.025$), and shorter postoperative hospital stay (5.1 days *vs.* 6.2 days, $P = 0.045$). The Pringle maneuver was used in the fourth case of SPR-LLS, after which the surgical time decreased. From the 9th case onwards, it was maintained at a similar level to the mean operative time of the L-LLS group (Fig. 2).

Table 1. Patients' baseline characteristics after propensity score matching

Characteristic	SPR-LLS group	L-LLS group	P-value
No. of patients	12	24	
Age (yr)	59.6 ± 8.7	61.0 ± 11.8	0.723[a)]
Sex, male:female	7:5	15:9	>0.999[b)]
Body mass index (kg/m^2)	23.6 ± 2.3	24.3 ± 2.7	0.445[a)]
ICG-R15	12.2 ± 4.1	14.0 ± 7.5	0.362[a)]
Total bilirubin (mg/dL)	0.64 ± 0.3	0.71 ± 0.6	0.810[a)]
PT (INR)	1.0 ± 0.1	1.1 ± 0.2	0.357[a)]
Platelet count (×10^3/μL)	187.6 ± 42.9	179.3 ± 65.0	0.839[a)]
α-FP	17.2 ± 7.1	76.7 ± 183.9	0.127[a)]
PIVKA	25.6 ± 12.6	36.2 ± 183.9	0.171[a)]
Albumin (mg/dL)	4.2 ± 0.4	4.1 ± 0.3	0.247[a)]
Liver cirrhosis			0.797[a)]
CTP A	12 (100)	22 (91.6)	
CTP B	0 (0)	2 (8.4)	
ASA PS classification			0.994[c)]
I	8	17	
II	4	7	
III	0	0	
Previous abdominal surgery	2 (16.7)	5 (20.8)	>0.999[a)]

Values are presented as number only, mean ± standard deviation, or number (%).
SPR-LLS, single-port robotic left lateral sectionectomy; L-LLS, laparoscopic left lateral sectionectomy; ICG-R15, indocyanine green retention rate at 15 minutes; INR, international normalized ratio; PIVKA, PIVKA, pretein induced by vitamin K absence or antagonist; CTP, Child-Turcotte-Pugh score; ASA, American Society of Anesthesiology; PS, physical status.
[a)]Student t-test; [b)]chi-square test; [c)]Kruskal-Wallis test.

Table 2. Peri- and postoperative details of patients after propensity score matching

Variable	SPR-LLS group (n = 12)	L-LLS group (n = 24)	P-value
Operative time (min)	151.8 ± 36.5	115.1 ± 32.7	0.004[a)]
Estimated blood loss (mL)	121.2 ± 29.9	175.4 ± 104.4	0.025[a)]
Pringle maneuver	9 (75.0)	12 (50.0)	0.282[a)]
Transfusion	0 (0)	2 (8.3)	0.797[a)]
Tumor size (cm)	2.5 ± 1.3	2.8 ± 1.5	0.077[a)]
Negative of resection margin	12 (100)	24 (100)	>0.999[a)]
Pathology			
HCC	11	22	
CCC		1	
Combine HCC and CCC	1	1	
Overall complication, CD grade	1 (8.3)	3 (12.5)	0.966[b)]
≤II	1 (8.3)	3 (12.5)	
≥III	0 (0)	0 (0)	
Complication details			
Ascites	0	0	
Pleural effusion	0	0	
Wound infection	0	2	
Fluid collection at operation site	1	1	
Incisional hernia	0	0	
Postoperative hospital stay (day)	5.1 ± 1.6	6.2 ± 1.6	0.045

Values are presented asmean ± standard deviation, number (%), or number only.
SPR-LLS, single-port robotic left lateral sectionectomy; L-LLS, laparoscopic left lateral sectionectomy; HCC, hepatocellular carcinoma; CCC, cholangiocarcinoma; CD, Clavien-Dindo classification.
[a)]Mann-Whitney U-test; [b)]Fisher exact test.

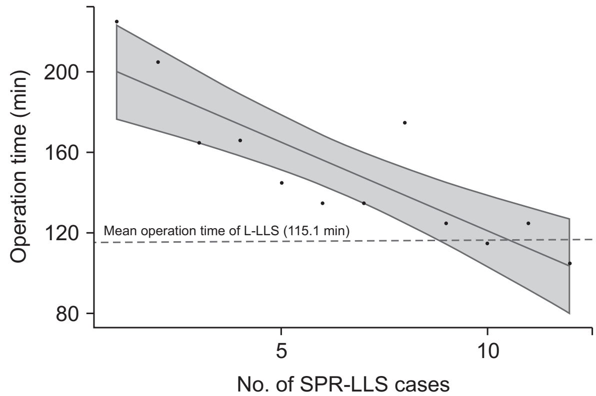

Fig. 2. Correlation analysis between operation time and cumulative cases of single-port robotic left lateral sectionectomy (SPR-LLS).

DISCUSSION

To the best of our knowledge, this is the first study to compare the clinicopathologic and surgical outcomes between laparoscopic surgery and single-port robotic surgery in patients with malignant tumors using PSM.

Data comparing robotic and laparoscopic liver resections are limited, with conflicting results. Several recent studies on complex major liver resections, such as right hepatectomy and right posterior sectionectomy, have suggested the advantages of the robotic platform over laparoscopy, including lower blood loss, open conversion, postoperative hospital stay, and morbidity. Similarly, a study comparing simpler minor resections of tumors in the anterolateral location demonstrated lower open conversion rates and less blood loss in the robotic group than in the laparoscopic group [13-17].

We also observed a lower median blood loss in the R-LLS group. This finding is consistent with that reported in a recent study by Hu et al. [8], which also showed reduced blood loss in complex cases of LLS. This may have been influenced by the performance of more Pringle maneuvers in the SPR-LLS group and by the higher-magnification visualization of the robotic system. As for SPR-LLS, a crushing technique was used because it is difficult to use instruments such as the CUSA in the system. In this case, more effective liver resection was possible when the Pringle maneuver was used.

Several studies have previously reported that the operation time for R-LLS was longer compared to that for L-LLS [18-20]. Our results showed that the mean operation time of SPR-LLS was higher than that of L-LLS. However, as the number of SPR-LLS cases increased, the surgical time decreased; in the 9th case, the surgical time of SPR-LLS reached a level similar to that of L-LLS. This is believed to be a combination of the convenience of the robotic system and the relatively low surgical difficulty associated with LLS. For an initial learning curve, LLS may also be a good indication before stepping up to more complex liver resections for surgeons who want to start minimally invasive liver resections using single-port robotic systems.

The increased operation time may be related to perioperative complications; however, complications were comparable between the robotic and laparoscopic groups (8.3% *vs.* 12.5%, $P > 0.999$).

Ji et al. [20] reported lower complications in robotic liver resection than in laparoscopic liver resection (7.8% *vs.* 10.5%, respectively), whereas Packiam et al. [21] reported rates of 27% in the robotic group and 0% in the laparoscopic group. However, the largest comparative study reported similar complication rates (19% *vs.* 26%, respectively) [5]. Our data revealed similar complication rates in the laparoscopic and robotic groups (12.5% *vs.* 8.3%).

The da Vinci SP system enables surgeons to perform delicate and complex operations through one small incision. The da Vinci SP system consists of several key components including an ergonomically designed console where the surgeon sits while operating, a patient-side cart where the patient is positioned during surgery, interactive robotic arms, a 3D high definition vision system, and a proprietary endowrist arm. Distal triangulation of the SP robot arm provides a greater degree of freedom of movement, particularly in narrow and deep access areas. However, there are some limitations to SP systems. Currently, energy devices and staplers compatible with the SP system, such as the CUSA, have not been developed. The authors attempted to overcome this limitation to some extent by using a uniport, stapler, and suction device without an additional port and by using the Pringle maneuver method. For beginners, this bleeding issue often acts as an important obstacle in overcoming the learning curve of surgical procedures. In particular, when applying a single-port robotic platform in liver surgery, as mentioned above, more careful and meticulous surgery is needed because, in reality, equipment such as energy devices are not yet available.

This study had several limitations. Because of the small study scale and selection bias, differences between the robotic and laparoscopic groups may lack significance. Due to the small number of patients in the robotic LLS group, survival outcomes could not be evaluated. Further large-scale, multicenter, prospective, or retrospective studies should be performed to overcome these limitations.

In conclusion, SPR-LLS using the da Vinci SP system was comparable to L-LLS in terms of surgical outcomes. Robotic procedures are associated with less blood loss and shorter postoperative length of stay. These findings suggest that minor hepatic resection with the da Vinci SP system is technically feasible and safe for selected patients.

SUPPLEMENTARY MATERIALS

Supplementary Video can be found via https://doi.org/10.4174/astr.2024.106.2.78.

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Conflicts of interest

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

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