



# Laparoscopic anatomical versus non-anatomical liver resection for hepatocellular carcinoma in the posterosuperior segments: a propensity score matched analysis

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**Background:** Since laparoscopic anatomical resection (LAR) for tumors, especially located in the posterosuperior (PS) segments of the liver remains difficult, laparoscopic non-anatomical resection (LNAR) are generally preferred. To compare the clinical outcomes between LAR and LNAR for hepatocellular carcinoma (HCC) located in the PS segments.

**Methods:** We retrospectively reviewed the data for 1,029 patients who underwent hepatectomy for HCC between 2004 and 2019. Of 167 patients who underwent laparoscopic hepatectomy for HCC in PS segments, 64 underwent LNAR and 103 underwent LAR. Patients were matched one-to-one using propensity score matching (46:46).

**Results:** LNAR was associated with significantly shorter operation time ( $P=0.001$ ), lower estimated blood loss ( $P=0.001$ ), lower transfusion rate ( $P=0.006$ ) and shorter hospital stay ( $P=0.012$ ) than LAR. The respective 1-, 3-, and 5-year overall survival rates (LAR: 95.3%, 87.1%, and 77.8%; LNAR: 96.7%, 91.6%, and 85.0%;  $P=0.262$ ) and recurrence-free survival rates (LAR: 75.7%, 70.3%, and 68.9%; LNAR: 81.8%, 58.3%, and 55.3%;  $P=0.879$ ) were similar. The intrahepatic recurrence rate was significantly higher in LNAR group than in LAR group (78.6% vs. 57.1%,  $P=0.023$ ), but the post-recurrence treatments differed significantly between the two groups ( $P=0.016$ ); the re-resection rate was much greater in the LNAR group (45.0% vs. 0%) group. The respective 1-, 3-, and 5-year post-recurrence survival rates were similar in the LAR and LNAR groups ( $P=0.212$ ). After recurrence, survival in re-resection group was significantly greater than not ( $P=0.026$ ).

**Conclusions:** LNAR is safe and feasible for HCC located in PS segments, and provided acceptable oncologic outcomes that are comparable to those of LAR. LNAR can be considered for patient with tumor located in PS segment when LAR is not feasible.

**Keywords:** Laparoscopy; hepatectomy; carcinoma, hepatocellular; recurrence

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## Introduction

Liver resection is a potentially curative treatment for hepatocellular carcinoma (HCC). However, recurrence after surgery remains a major challenge in the management

of HCC (1,2). Post-surgical recurrence is thought to be due to tumor invasion of portal venous branches that allows the tumor cells to be disseminate to other regions of the liver via the portal venous flow (3). Thus, it is believed

that anatomical resection (AR), which removes the tumor-bearing portal tributaries supplied by a major branch of the portal vein and hepatic artery, confers a survival benefit (4). Although several studies have demonstrated the oncological benefits of AR over non-anatomical resection (NAR) for HCC, the optimum liver resection technique remains controversial (5-7).

Recent advances in minimally invasive surgery have gradually accelerated the adoption of laparoscopic liver resection (LLR), and its role in liver surgery is becoming increasingly important. Several studies have demonstrated that LLR could provide favorable short- and long-term outcomes compared with open liver resection (OLR) (8-10). However, these earlier studies included a limited number of patients who underwent laparoscopic anatomical resection (LAR), especially in the posterosuperior (PS) segments of the liver (segments 1, 7, 8, and the superior part of segment 4). Although minor LLR is accepted as a curative treatment for HCC, LAR is not widely performed (11). LAR is a challenging procedure that should be performed by surgeons with experience of performing LLR. Although several studies have demonstrated feasible outcomes of LAR, the oncological benefits of LAR for HCC remain unclear.

LLR of PS segments is considered technically challenging because these anatomical locations are difficult to access laparoscopically (12,13). Because LLR is rarely performed for tumors located in the PS segments, to our knowledge, there have been no studies comparing LAR and laparoscopic non-anatomical resection (LNAR) for tumors in PS segments. Therefore, in this study, we compared the clinical outcomes between LAR and LNAR for HCC located in the PS segments. Patients in both groups were matched using propensity score matching (PSM). We present this article in accordance with the STROBE reporting checklist (available at <https://hbsn.amegroups.com/article/view/10.21037/hbsn-21-578/rc>).

## Methods

### *Patients and data collection*

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). In accordance with guidelines for human subjects' research, this retrospective study was approved by the institutional review board of Seoul National University Bundang Hospital, Seongnam, Korea, an academic hospital affiliated to Seoul National University, College of Medicine (Approval No.

B-2021-633).

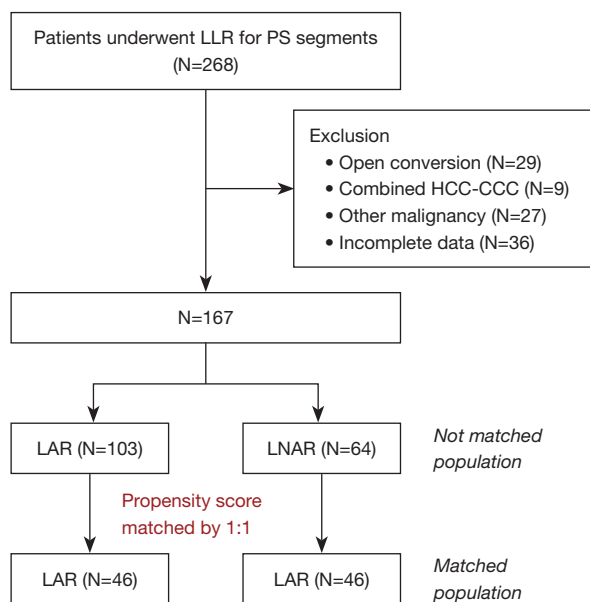
*Figure 1* shows the patient flowchart. A total of 1,029 consecutive patients with HCC underwent hepatectomy between January 2004 and December 2019. Patients included in this study were identified as follows. First, we extracted the records for 268 patients who underwent LLR for a tumor located in the PS segments by the same surgical team. We subsequently excluded cases who required open conversion [N=29, 18 patients in LAR (14.9%) *vs.* 11 patients in LNAR (14.6%), P=0.891], patients with combined HCC-cholangiocarcinoma (N=9), patients with other malignancies (N=27), and patients with incomplete data (N=36). A total of 167 patients, including 103 who underwent LAR and 64 who underwent LNAR, were finally included in this study.

The decision to perform LAR or LNAR was made based on the tumor size, location, and hepatic function. LAR was preferred, if feasible, for patients with a centrally located tumor and normal hepatic function. Right hemihepatectomy is preferred when the tumor is located close to large vessel such as right hepatic vein and right posterior Glissonean pedicle with sufficient remnant liver volume and normal liver function. LNAR was performed for patients with peripherally located tumor and/or impaired liver function.

### *LAR and LNAR procedures*

The LLR procedure for tumors located in the PS segments has been reported (14-17). The patients were placed in the lithotomy position and were tilted to a 30° reverse Trendelenburg position with right-side-up adjustment. The surgeon was positioned between the patient's legs or the patient's right side. After establishing pneumoperitoneum through a sub-umbilical 11-mm camera port, four additional ports were created. In some patients, additional intercostal ports were placed at the seventh and ninth intercostal spaces (18). A flexible laparoscope was used.

When performing LAR for tumors located in PS segments, we generally used the Glissonean approach. First, after performing cholecystectomy with usual methods, the right liver was mobilized from the inferior vena cava and the diaphragm. After dissecting the major Glissonean pedicle of the right posterior section, further hepatic parenchymal dissection was performed from the peripheral side until we reached the branches of the Glissonean pedicles of the PS segment. After isolating and ligating the Glissonean pedicle, the transection plane was determined based on the ischemic line. This ischemic line and laparoscopic



**Figure 1** Patient flow chart. LLR, laparoscopic liver resection; PS, posterosuperior; HCC-CCC, hepatocellular carcinoma-cholangiocarcinoma; LAR, laparoscopic anatomical resection; LNAR, laparoscopic non-anatomical resection.

intraoperative ultrasonography (IOUS) help guide the plane of parenchymal dissection.

The surgical procedures for LNAR differed according to the tumor locations. First, laparoscopic IOUS was performed to detect the tumor and its relationship with the nearby vasculature. Moreover, we frequently used the IOUS to obtain a sufficient surgical margin. Then, parenchymal dissection was performed using a harmonic scalpel or cavitron ultrasonic surgical aspirator to obtain an adequate resection margin (Figure 1).

### Variables

The demographic and preoperative data (etiology, liver function, tumor factors) were compared between patients who underwent LAR and LNAR. We used 1:1 PSM to compensate for selection bias and to match patients based on preoperative clinical factors. A total of 92 patients were selected, with 46 patients per each group. After adjusting for these factors, the short- and long-term operative outcomes were compared between the two matched groups. Postoperative complications that occurred within 30 days after surgery were graded using the Clavien-Dindo classification (19).

### Recurrence

Patients were followed by abdominal computed tomography and blood tests, including measurement of tumor markers every 3 months for the first 2 years after primary surgery, and then every 3–6 months thereafter. Intrahepatic recurrence was divided into right or left lobe. Early recurrence was defined as disease relapse within 2 years after hepatectomy.

Patients with postsurgical recurrence were managed by locoregional treatment (LT) or palliative treatment (PT). LT comprised re-resection or radiofrequency ablation (RFA) if the recurrence was localized. LT in extrahepatic recurrence is performed when the patient showed the oligometastatic disease, absent/controlled intrahepatic hepatocellular carcinoma and satisfactory liver function and performed status were deemed for eligible for extrahepatic metastectomy. PT comprised received transcatheter arterial chemoembolization (TACE) or conservative management with sorafenib if the tumor was not amenable to locoregional treatment.

### Survival

Overall survival (OS) was defined as the time from primary surgery to the date of death regardless of cause. Recurrence-free survival (RFS) was defined as the time from primary surgery to the first documented detection of recurrence during regular follow-up. Survival after recurrence (SAR) was the time from the first day of identified recurrence to the date of death or the date of last follow-up. A subgroup analysis was performed to compare the SAR according to the treatment method after recurrence (i.e., LT vs. PT).

### Statistical analysis

All statistical analyses were performed using SPSS software for Windows, version 25 (IBM Corporation, Armonk, NY, USA). Clinical data were summarized using descriptive analyses, and all continuous values are presented as the mean and standard deviation. Student's *t*-test or the Mann-Whitney *U* test were used to compare continuous variables, and Pearson's  $\chi^2$  test was used to compare categorical variables. All *P* values of <0.05 were considered statistically significant. Survival was estimated using the Kaplan-Meier method, and compared using the log-rank test.

**Table 1** Patient characteristics

Variables	Unmatched			After applying PSM		
	LAR (N=103)	LNAR (N=64)	P value	LAR (N=46)	LNAR (N=46)	P value
<b>Demographic data</b>						
Age (years)	59.4±11.4	60.2±9.9	0.342	59.8±10.9	61.6±8.2	0.252
Male	77 (80.8)	54 (84.4)	0.177	29 (63.0)	38 (82.6)	0.060
BMI (kg/m <sup>2</sup> )	24.7±3.6	25.1±2.9	0.491	24.8±3.6	25.1±2.9	0.444
HTN	42 (40.8)	28 (43.8)	0.748	12 (26.1)	16 (34.7)	0.831
Diabetes	23 (22.3)	14 (21.9)	1.000	6 (13.0)	10 (21.7)	0.410
Prior abdominal surgery	22 (21.4)	19 (29.7)	0.268	10 (21.7)	14 (30.4)	0.336
<b>Preoperative data</b>						
Etiology			0.965			0.470
Hepatitis B	66 (64.1)	41 (64.1)		32 (69.6)	27 (58.7)	
Hepatitis C	7 (6.8)	5 (7.8)		5 (10.9)	5 (10.9)	
MELD score	7.6±1.6	7.7±1.2	0.220	7.7±1.3	7.8±1.4	0.277
Child-Pugh score			0.372			1.000
A	101 (98.1)	61 (95.3)		45 (97.8)	45 (97.8)	
B	2 (1.9)	3 (4.7)		1 (2.2)	1 (2.2)	
Bilirubin (mg/dL)	0.8±0.4	0.8±0.3	0.364	0.8±0.4	0.8±0.4	0.481
ALT (IU/L)	50.9±65.8	36.1±27.2	0.028	42.5±61.3	39.9±32.7	0.515
AST (IU/L)	51.1±80.0	41.7±33.3	0.307	49.1±109.5	47.3±42.5	0.336
Albumin (g/dL)	4.3±0.4	4.2±0.4	0.724	4.2±0.4	4.3±0.4	0.185
INR	1.1±0.1	1.1±0.1	0.639	1.1±0.1	1.1±0.1	0.232
Platelet count (×10 <sup>3</sup> /μL)	193.4±66.9	163.6±65.0	0.276	183.9±78.7	170.4±62.6	0.396
Prior TACE	20 (19.4)	16 (25.0)	0.441	12 (26.1)	9 (19.6)	0.620
Prior RFA	9 (8.7)	3 (4.7)	0.375	5 (10.8)	2 (4.3)	0.158
AFP (ng/mL)	836.0±6,953.3	217.8±1,113.7	0.046	351.9±826.3	332.6±658.6	0.874
Tumor size (cm)	4.0±2.3	2.0±0.9	0.001	2.6±1.0	2.3±1.0	0.741

All variables are presented as the mean ± standard deviation or n (%) of patients. PSM, propensity score matching; LAR, laparoscopic anatomical resection; LNAR, laparoscopic non-anatomical resection; BMI, body mass index; HTN, hypertension; MELD, Model for End-stage Liver Disease; ALT, alanine aminotransferase; AST, aspartate aminotransferase; INR, international normalized ratio; TACE, transarterial chemoembolization; RFA, radiofrequency ablation; AFP,  $\alpha$ -fetoprotein.

## Results

### Patient demographics

Table 1 shows the patient characteristics of all patients, as well as both groups matched by PSM. Before PSM (LAR vs. LNAR), preoperative alanine aminotransferase (50.9±65.8 vs. 36.1±27.2 IU/L, P=0.028),  $\alpha$ -fetoprotein (836.0±6,953.3

vs. 217.8±1,113.7 ng/mL, P=0.046), and tumor size (4.0±2.3 vs. 2.0±0.9 cm, P=0.001) were significantly difference between groups. After PSM, the patient characteristics were well balanced in both groups, with no significant differences in demographic variables (age, sex, body mass index, hypertension, diabetes mellitus, previous abdominal surgery), liver-related variables (virology, Model for End-

**Table 2** Outcomes of surgery in the propensity-matched groups

Variables	LAR (N=46)	LNAR (N=46)	P value
Operative type			0.001
Right hemihepatectomy	12 (26.1)	–	
Right anterior sectionectomy	4 (8.7)	–	
Right posterior sectionectomy	14 (30.4)	–	
Segmentectomy	16 (34.8)	–	
Tumorectomy	–	46 (100.0)	
Operative data			
Operation time (min)	408.9±142.9	143.1±50.8	0.001
Estimated blood loss (mL)	917.5±152.9	333.8±259.3	0.001
Transfusion	14 (30.4)	3 (6.5)	0.006
Pringle maneuver	19 (41.3)	21 (45.7)	0.834
Postoperative data			
Hospital stay (days)	7.8±3.3	5.7±2.7	0.012
C-D complications			0.134
IIIa	3 (6.5)	4 (8.7)	
IIIb	1 (2.2)	0	
IV	0	0	
V	0	0	
Pathologic data			
Tumor size (cm)	2.7±1.0	2.3±0.7	0.088
Surgical margin (cm)	1.1±1.3	1.0±0.5	0.162
Microvascular invasion	14 (40.0)	12 (34.3)	0.805
Serosal invasion	10 (21.7)	10 (21.7)	1.000
Tumor stage			0.268
I	24 (52.2)	27 (58.7)	
II	18 (39.1)	17 (37.0)	
III	2 (4.3)	0	
IV	0	0	
Total necrosis	2 (4.3)	2 (4.3)	
Cirrhosis	19 (41.3)	28 (60.9)	0.095

All variables are presented as the mean ± standard deviation or n (%) of patients. LAR, laparoscopic anatomical resection; LNAR, laparoscopic non-anatomical resection; C-D, Clavien-Dindo.

stage Liver Disease score, Child-Pugh score) and tumor-related factors (previous TACE, RFA, and tumor size).

### **Surgical outcomes**

Table 2 shows the surgical outcomes in the PSM groups. The mean operation time (LAR *vs.* LNAR; 408.9±142.9

*vs.* 143.1±50.8 min, P=0.001), estimated blood loss (EBL; 917.5±152.9 *vs.* 333.8±259.3 mL, P=0.001), and intra-operative transfusion rate (30.4% *vs.* 6.5%, P=0.006) were significantly greater in the LAR group than in the LNAR group. The mean length of hospitalization after surgery was significantly longer in the LAR group than in the LNAR group (7.8±3.3 *vs.* 5.7±2.7 days, P=0.012). The frequency

**Table 3** Clinical characteristics of recurrent HCC in the propensity score-matched groups

Variables	LAR (N=46)	LNAR (N=46)	P value
Recurrence, n (%)	14 (30.4)	14 (30.4)	1.000
Recurrence site, n (%)			0.023
Intrahepatic	8 (57.1)	11 (78.6)	
Right lobe	2	11	
Left lobe	6	0	
Extrahepatic	5 (35.7)	1 (7.1)	
Both	1 (7.1)	2 (14.3)	
Time to recurrence, n (%)			0.695
Early recurrence ( $\leq 24$ months)	6 (42.9)	5 (35.7)	
Late recurrence ( $> 24$ months)	8 (57.1)	9 (64.3)	
Treatment after recurrence, n (%)			0.016
Curative intent treatment			
Re-resection	0	5 (35.7)	
RFA	1 (7.1)	3 (21.4)	
RFA + TACE	3 (21.4)	0	
Palliative treatment			
TACE	2 (14.3)	3 (21.4)	
Chemotherapy or supportive therapy	8 (57.1)	3 (21.4)	

HCC, hepatocellular carcinoma; LAR, laparoscopic anatomical resection; LNAR, laparoscopic non-anatomical resection; RFA, radiofrequency ablation; TACE, transarterial chemoembolization.

of major postoperative complications (Clavien-Dindo grade  $\geq$  IIIa) was not significantly different between the two groups ( $P=0.134$ ). There were no in-hospital deaths.

Regarding pathological data (LAR *vs.* LNAR), tumor size ( $2.7 \pm 1.0$  *vs.*  $2.3 \pm 0.7$  cm,  $P=0.088$ ) and surgical margin ( $1.1 \pm 1.3$  *vs.*  $1.0 \pm 0.5$  cm,  $P=0.162$ ) were similar in both groups. The frequencies of microvascular invasion (40.0% *vs.* 34.3%,  $P=0.805$ ) and serosal invasion (21.7% *vs.* 21.7%,  $P=1.000$ ), and tumor stage ( $P=0.268$ ) were similar in both groups. The frequency of patients with pathologically confirmed liver cirrhosis was also similar in the LAR and LNAR groups (41.3% *vs.* 60.9%,  $P=0.095$ ).

#### **Clinical characteristics of patients with recurrent tumors**

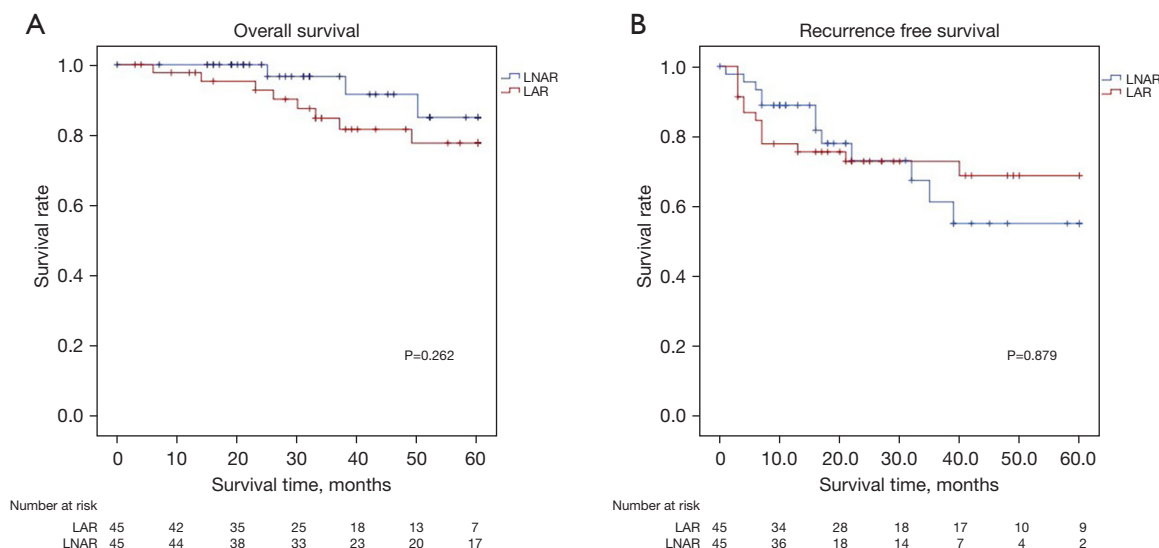
Table 3 compares the recurrence patterns and secondary treatment for two groups. After a median follow-up of 50 months (range, 7–175 months), 14 patients (30.4%) in the LAR group and 14 patients (30.4%) in the LNAR

group experienced recurrence ( $P=1.000$ ). The intrahepatic recurrence rate was significantly higher in LNAR group than in LAR group (78.6% *vs.* 57.1%,  $P=0.023$ ). Among the patients who experienced intrahepatic recurrence, patients with LNAR more frequently experienced recurrence in the right lobe. The incidence of early recurrence was similar in the LAR and LNAR groups (42.9% *vs.* 35.7%,  $P=0.695$ ).

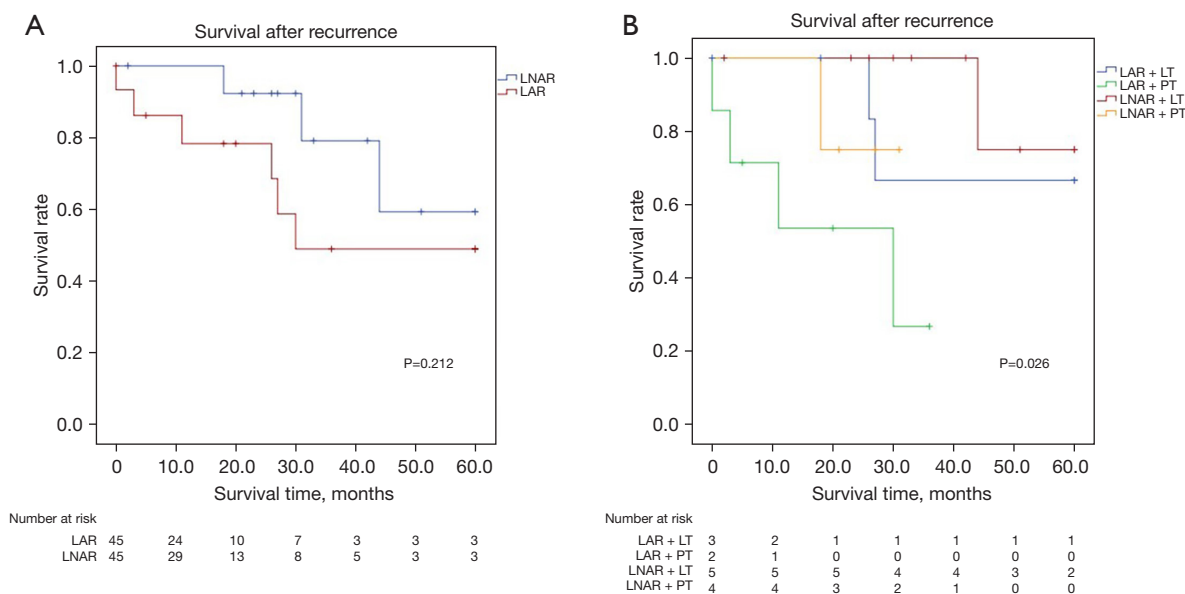
Following recurrence, the treatment options were categorized as LT or PT. The secondary treatment differed significantly between the two groups ( $P=0.016$ ). In particular, the re-resection rate was significantly greater in the LNAR group (45.0% *vs.* 0%). The resection type among patients who underwent re-resection was tumorectomy.

#### **Survival**

Figure 2 shows the cumulative survival curve for the LAR and LNAR groups (with PSM). The respective 1-, 3-,



**Figure 2** Survival curve of patients undergoing LAR and LNAR for PS lesions in the propensity-matched group. (A) Overall survival; (B) recurrence free survival. LNAR, laparoscopic non-anatomical resection; LAR, laparoscopic anatomical resection; PS, posterosuperior.



**Figure 3** SAR of patients in the propensity-matched group. (A) Overall SAR curves; (B) SAR curve based on the treatment type after recurrence. LNAR, laparoscopic non-anatomical resection; LAR, laparoscopic anatomical resection; LT, locoregional treatment; PT, palliative treatment; SAR, survival after recurrence.

and 5-year OS (LAR: 95.3%, 87.1%, and 77.8%; LNAR: 96.7%, 91.6%, and 85.0%;  $P=0.262$ ) and the 1-, 3-, and 5-year RFS (LAR: 75.7%, 70.3%, and 68.9%; LNAR: 81.8%, 58.3%, and 55.3%;  $P=0.879$ ) were not significantly different between the two groups.

Figure 3A shows the overall SAR curves. The 1-, 3-, and

5-year SAR rates were 78.3%, 49.0%, and 49.0% in the LAR group vs. 92.3%, 79.1%, and 59.3% in the LNAR group, respectively ( $P=0.212$ ). Figure 3B shows the SAR curve based on the treatment performed after recurrence. The SAR was significantly greater in the LT group than in the PT group ( $P=0.026$ ).

## Discussion

LLR for a tumor located in PS segments is considered particularly challenging because of its location in the deepest region of the abdominal cavity, and its relationship to the hepatic veins and Glissonean pedicles (20-22). LAR procedures for PS segments, including laparoscopic posterior sectionectomy and laparoscopic S6 or S7 segmentectomy, are often considered major hepatectomy, despite not satisfying the International Hepato-Pancreato-Biliary Association (IHPBA) Brisbane definition of major hepatectomy (23). LNAR of small tumors located in the PS segments in patients with normal hepatic function is also considered technically challenging because the transection planes can be curved or angled (24). For these reasons, it is controversial whether LAR or LNAR is the optimal approach for a tumor located in the PS segments. Although, several studies have demonstrated the feasibility of LAR (8), there are no studies comparing the clinical outcomes between LAR and LNAR for tumors located in PS segments. General, normal liver function allows either LAR or LNAR to be performed safely. However, in patients with liver cirrhosis, LAR sometimes leads to post-hepatectomy liver failure (25). Thus, preoperative liver function and tumor characteristics are important confounding factors that should be considered when comparing LAR and LNAR, and they may impact on the clinical outcomes (26). Therefore, we used PSM to minimize potential confounding effects in this study. Thereby, we compared the short- and long-term outcomes between LAR and LNAR for tumors located in PS segments by applying PSM.

This study revealed better short-term outcomes of LNAR *vs.* LAR in terms of operation time, EBL, and hospital stay. Troisi *et al.* reported that resection involving PS segments was an independent risk factor for open conversion during LLR, and bleeding was the main reason for conversion (21). When performing LAR in our institution, we generally adopt the Glissonean approach. LAR using the Glissonean approach is a challenging procedure associated with increased risk of bleeding. Besides, the LAR should expose the main trunk of the hepatic vein, which can also result in excessive blood loss. This may explain the greater blood loss and longer operation time in the LAR group. Several studies have demonstrated that increased intraoperative blood loss is significantly correlated with poor prognosis following hepatectomy for HCC (27-29). In this context, reducing intraoperative blood loss should be considered in order to

improve the oncological outcomes.

In terms of long-term outcomes, the OS and RFS were not significantly different between the LAR and LNAR groups, but some differences in the recurrence pattern and SAR were detected. Early recurrence ( $\leq 2$  years postoperatively) is associated with aggressive tumor biology (29). In this study, both groups showed an even distribution in the time to recurrence. Thus, we consider that the tumor biology was similar in both groups. However, there were differences in the pattern of recurrence and the type of post-recurrence treatment between the two groups. Intrahepatic recurrence, especially in the right lobe, was more prevalent in the LNAR group. One possible explanation is that remnant ischemia in the LNAR group may influence the intrahepatic recurrence after surgery (30). By comparison, recurrence in the left lobe and extrahepatic metastasis were more common in the LAR group. A recent meta-analysis found no significant difference in the type of recurrence between open AR and NAR (31). However, in our study, despite the similar tumor biology in both groups, the reason for the higher incidence of extrahepatic recurrence in the LAR group is unclear. It may be suggested that excessive blood loss may promote tumor spillage and hematogenous spread during the operation, which could accelerate recurrence (28,32,33). Alternatively, high volumes of blood loss may be associated with systemic hypotension and impaired organ delivery to vital organs. This in turn may promote systemic inflammation and a cytokine milieu that may impede antitumor immunity (28,34). Due to the different patterns of recurrence, the types of post-recurrence treatment differed between the two groups. The prognosis of recurrent HCC after surgery is strongly related to whether the patient is a candidate for local treatment of the lesion (35-37). According to a study by Shimada *et al.*, the survival rate was higher in patients with recurrent HCC who underwent locoregional treatment (e.g., hepatectomy, ablation, and percutaneous ethanol injection) than in patients with systemic recurrence who were ineligible for local treatment (38). In this study, many patients in the LNAR group underwent locoregional treatment after recurrence. For this reason, although the 3-, and 5-year RFS rate of the LNAR group is relatively lower than in LAR group, the OS of the two groups was similar. The reason for this trend is thought to be the difference in treatment option after recurrence. The main benefit of LNAR is that the chance of performing multimodal treatment is higher on the tumor recurrence, and repeat resection can be performed.



There are several limitations in this study. First, this study includes its retrospective nature and that data were obtained from a single center. Although both groups were well balanced by applying PSM, the small sample size is a major limitation. A multicenter, prospective study is necessary to help reach a firm conclusion. Second, in most patients who underwent LNAR, the tumor size was less than 3 cm. Therefore, we performed subgroup analysis based on tumor size (Table S1). According to results, although the short-term outcomes, such as operation time, estimated blood loss and hospital stays were significantly higher in LNAR group, the surgical margin was significantly lower in LNAR group. Therefore, the results of this study appear to be applicable to relatively small-sized tumors.

## Conclusions

In conclusion, our study has demonstrated that LNAR offers better short-term outcomes than LAR in terms of operation time, EBL, and length of hospital stay. Although, there were no significant differences in OS and RFS between LAR and LNAR, many patients in the LNAR group underwent treatment with a curative intent following recurrence. The present results suggest that LNAR can provide acceptable oncological outcome that are comparable to those of LAR for patients with HCC located in PS segments of the liver. LNAR can be considered for patients with relatively small-sized tumor located in PS segment when LAR is not feasible.

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## Footnote

*Reporting Checklist:* The authors have completed the STROBE reporting checklist. Available at <https://hbsn.amegroups.com/article/view/10.21037/hbsn-21-578/rc>

*Data Sharing Statement:* Available at <https://hbsn.amegroups.com/article/view/10.21037/hbsn-21-578/dss>

*Conflicts of Interest:* All authors have completed the ICMJE uniform disclosure form (available at <https://hbsn.amegroups.com/article/view/10.21037/hbsn-21-578/coif>). H.S.H. serves as an unpaid editorial board member of *Hepatobiliary Surgery and Nutrition*. J.Y.C. receives support

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*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. The present study was performed in accordance with the Declaration of Helsinki (as revised in 2013). Informed consent was obtained from all the patients prior to treatment, and for their data to be used for research purposes. In accordance with guidelines for human subjects' research, this retrospective study was approved by the institutional review board of Seoul National University Bundang Hospital, Seongnam, Korea, an academic hospital affiliated to Seoul National University, College of Medicine (Approval No. B-2021-633).

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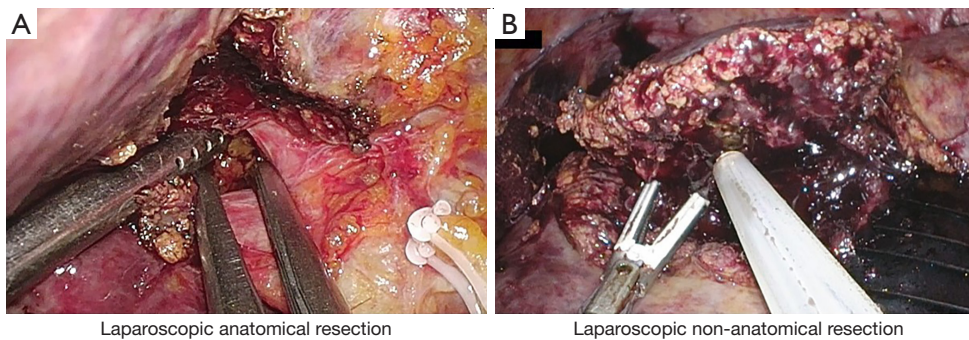
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**Table S1** Subgroup analysis based on tumor size (>3 cm) in unmatched population

Variables	LAR (N=61)	LNAR (N=7)	P value
<b>Operative data</b>			
Operation time (min), mean ± standard deviation	329.4±133.1	140.7±58.1	0.062
Estimated blood loss (mL), mean ± standard deviation	1,124.2±1,282.7	330.0±307.4	0.019
Transfusion, n (%)	18 (29.5%)	0	0.177
Pringle maneuver, n (%)	36 (59.0%)	4 (57.1%)	0.933
<b>Postoperative data</b>			
Hospital stay (days), mean ± standard deviation	9.2±4.7	6.8±5.1	0.020
C-D complications, n (%)			0.244
IIIa	5 (8.3%)	3 (40.0%)	
IIIb	3 (5.0%)	0	
IV	2 (3.3%)	0	
V	0	0	
<b>Pathologic data, mean ± standard deviation</b>			
Tumor size (cm)	5.6±2.5	3.6±0.4	0.027
Surgical margin (cm)	1.1±1.4	0.5±0.4	0.018



**Figure S1** Surgical step of LAR and LNAR.