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Original Article

International multicentre propensity score-matched analysis comparing robotic *versus* laparoscopic right posterior sectionectomy

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Abstract

Background: Minimally invasive right posterior sectionectomy (RPS) is a technically challenging procedure. This study was designed to determine outcomes following robotic RPS (R-RPS) and laparoscopic RPS (L-RPS).

Methods: An international multicentre retrospective analysis of patients undergoing R-RPS *versus* those who had purely L-RPS at 21 centres from 2010 to 2019 was performed. Patient demographics, perioperative parameters, and postoperative outcomes were analysed retrospectively from a central database. Propensity score matching (PSM) was performed, with analysis of 1 : 2 and 1 : 1 matched cohorts.

Results: Three-hundred and forty patients, including 96 who underwent R-RPS and 244 who had L-RPS, met the study criteria and were included. The median operating time was 295 minutes and there were 25 (7.4 per cent) open conversions. Ninety-seven (28.5 per cent) patients had cirrhosis and 56 (16.5 per cent) patients required blood transfusion. Overall postoperative morbidity rate was 22.1 per cent and major morbidity rate was 6.8 per cent. The median postoperative stay was 6 days. After 1 : 1 matching of 88 R-RPS and L-RPS patients, median (i.q.r.) blood loss (200 (100–400) *versus* 450 (200–900) ml, respectively; $P < 0.001$), major blood loss (> 500 ml; $P = 0.001$), need for intraoperative blood transfusion (10.2 *versus* 23.9 per cent, respectively; $P = 0.014$), and open conversion rate (2.3

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versus 11.4 per cent, respectively; P = 0.016) were lower in the R-RPS group. Similar results were found in the 1 : 2 matched groups (66 R-RPS *versus* 132 L-RPS patients).

Conclusion: R-RPS and L-RPS can be performed in expert centres with good outcomes in well selected patients. R-RPS was associated with reduced blood loss and lower open conversion rates than L-RPS.

Introduction

Minimally invasive hepatectomy (MIH) is increasingly adopted and becoming standard of care in many high-volume specialist hepatopancreatobiliary (HPB) centres around the world[1–3]. The increased adoption is, in part, due to rapid and widespread dissemination of standardized surgical techniques, development of improved technology for visualization of the operative field, equipment advancement, and increasing evidence of short- and long-term benefits of MIH compared with open surgery. These benefits include shorter hospital stay, fewer wound complications, faster return to work, and lower perioperative morbidity without compromising oncological outcomes[4–7]. Several major consensus conferences over the years have continued to define the role of MIH for surgeons worldwide, moving from guidelines for patient selection, training, and evaluations for safety and feasibility to recent discussions on precision anatomical resections[8–12] .

While adoption of laparoscopic hepatectomy in general has been widespread, use of minimally invasive techniques for major hepatectomy or difficult resections has still been mainly confined to more experienced centres[13–15]. Amongst the difficult resections include lesions in the posterior superior segments of the liver or anatomical resections involving these segments such as formal bisegmentectomy of segment 6/7 or right posterior sectionectomy (RPS)[16]. These procedures performed laparoscopically would be rated with a minimum score of 6 (intermediate) and above (expert), according to the Iwate criteria[17]. Similarly, RPS is graded as a procedure with high difficulty, based on the Institut Mutualiste Montsouris (IMM) scoring system[18]. Technical challenges encountered during RPS include a long horizontal cutting plane with a wide area of transection, difficulty in isolating the posterior pedicle, dissection to expose the right hepatic vein (RHV), and identifying the root of the RHV – all of which carry a risk of catastrophic bleeding, as well as oncological compromise with poor surgical technique in inexperienced hands. Hence, not surprisingly, reports of laparoscopic RPS (L-RPS) in the current literature have remained limited to studies with small sample sizes[19–22].

Robotic hepatectomy (RH) shows potential improvement over traditional laparoscopy due to the presence of integrated three-dimensional high definition (HD) immersive visualization with indocyanine green (ICG) Firefly, improved scalable dexterity of surgical instruments, stable-console surgeon-controlled camera with 10× magnification, and integrated multiscreen inputs via TilePro™[23]. However, barriers such as high cost, limited instrumentation, lack of an ultrasonic aspirator, possible need for a bedside specialist surgeon, and limited access continue to impede its wider adoption. Furthermore, despite its theoretical advantages, the actual advantages of RH over conventional laparoscopic hepatectomy remain debatable[24,25]. To date, studies comparing laparoscopic hepatectomy *versus* RH have remained limited to small retrospective studies[26,27] .

Given limited evidence on outcomes of MIH for RPS, this large multicentre study was conducted. The primary objective was to analyse the outcomes of robotic RPS (R-RPS) *versus* laparoscopic posterior sectionectomies (L-RPS) performed in 21 HPB centres specialized in MIH . To our knowledge, this is the largest study to date on MIH for RPS, and the only study comparing the outcomes of R-RPS *versus* L-RPS.

Methods

This was an international multicentre retrospective analysis of patients undergoing either L-RPS or R-RPS at 21 HPB centres from

Fig. 1 World map of 21 centres of the International Robotic and Laparoscopic Liver Resection Study Group

2010 to 2019 (Fig. 1). All participating institutions were given their respective approvals according to their local centre's requirements. This study was approved by the Singapore General Hospital Institution Review Board and the requirement for patient consent was waived. Anonymized data were collected in the individual centres, and were collated and analysed centrally at the Singapore General Hospital.

In this study, only patients who underwent purely laparoscopic or robot-assisted laparoscopic surgery were included. Patients who had laparoscopic-assisted (hybrid) and hand-assisted laparoscopic resections were excluded. Similarly, those undergoing donor hepatectomy for transplant and hepatectomy with bilioenteric anastomoses were also excluded.

Definitions

RPS was defined, according to the 2000 Brisbane classification, as resection of segments 6 and 7[28]. The diameter of the largest lesion was used in cases of multiple tumours. Postoperative complications were classified according to the Clavien–Dindo classification and recorded for up to 30 days or during the same hospitalization[29]. Difficulty of resections was rated according to the Iwate score[17].

Statistical analysis

Propensity score matching (PSM) was performed to minimize confounding and selection bias[30,31]. Before propensity score estimation, missing baseline covariates were addressed using multiple imputations (M = 50) by chained equations, with the following specifications: ordinal logistic regression for ordinal factor variables (for example, ASA classification status), five k-nearest neighbours for continuous variables (for example, tumour size), and augmented logistic regression for binary variables (for example, sex). Propensity scores were calculated from mixed-effects logistic models, taking into account age, sex, ASA status, previous abdominal or liver surgery, pathology, cirrhosis, Child–Pugh class, presence of portal hypertension, median tumour size, multifocality, concomitant surgeries excluding cholecystectomy, and Iwate difficulty grade. A random-effects term was used to denote participating institutions to better account for between-centre variation. We evaluated discriminatory power and calibration of the propensity score model using the methods of Lemeshow and Hosmer and c-index[32]. The final propensity score model exhibited an area under the receiver operating curve of 0.8162 (bias-corrected 95 per cent c.i. 0.8786 to 0.9263; Fig. S1) and good calibration (Fig. S2).

To ensure the robustness of conclusion, two separate sets of comparative analyses within 1 : 2 and 1 : 1 propensity score-matched cohorts were performed. Matches between the robotic and laparoscopic groups were identified using greedy matching with a caliper of 0.25 s.d. of the linear predictor (that is, logit of propensity score). After PSM, both groups were well balanced for all variables, as shown in Table 1 and Figs S3–S5.

In the unmatched cohort, comparisons of patient characteristics and perioperative outcomes between patients who underwent R-RPS and those who had L-RPS were performed using Mann–Whitney U test and Pearson's χ^2 test for continuous and categorical variables, respectively. Comparisons in the 1 : 2 and 1 : 1 matched cohorts considered the paired nature of the data; hence, paired analyses such as the mixed-effects quantile, conditional logistic, and mixed-effects multinomial or ordinal regression models were used for continuous, binary, and multivalued categorical variables, respectively. Statistical analyses were done using Stata version 16.0 (StataCorp LLC, College Station, TX, USA), and $P < 0.05$ were considered to indicate nominal statistical significance.

Table 1 Comparison between baseline clinicopathological characteristics of R-RPS *versus* L-RPS

		Unmatched cohort		
	Total **n = 340**	**R-RPS** **n = 96**	**L-RPS** **n = 244**	**P**
Median age (i.q.r.), years	61 (52–69)	60 (51–69)	61 (52–70)	0.533
Male sex, *n* (%)	214/339 (63.1%)	64/96 (66.7%)	150/243 (61.7%)	0.396
ASA score, *n* (%)				**< 0.001**
I	52/338 (15.4%)	12/96 (12.5%)	40/242 (16.5%)	
II	196/338 (58.0%)	43/96 (44.8%)	153/242 (63.2%)	
III	88/338 (26.0%)	40/96 (41.7%)	48/242 (19.8%)	
IV	2/338 (0.6%)	1/06 (1.0%)	1/242 (0.4%)	
Previous abdominal surgery, *n* (%)	115/340 (33.8%)	33/96 (34.4%)	82/244 (33.6%)	0.893
Previous liver surgery, *n* (%)	15/340 (4.4%)	4/96 (4.2%)	11/244 (4.5%)	0.890
Malignant pathology, *n* (%)	301/340 (88.5%)	89/96 (92.7%)	212/244 (86.9%)	0.129
Pathology type, *n* (%)				0.122
Hepatocellular carcinoma	179/340 (52.6%)	59/96 (61.5%)	120/244 (49.2%)	
Colorectal metastases	89/340 (26.2%)	21/96 (21.9%)	68/244 (27.9%)	
Other	72/340 (21.2%)	16/96 (16.7%)	56/244 (22.9%)	
Cirrhosis, *n* (%)	97/340 (28.5%)	35/96 (36.5%)	62/244 (25.4%)	**0.042**
Child–Pugh score, *n* (%)				0.104
No cirrhosis	243/340 (71.5%)	61/96 (63.5%)	182/244 (74.6%)	
A	93/340 (27.3%)	33/96 (34.4%)	60/244 (24.6%)	
B	4/340 (1.2%)	2/96 (2.1%)	2/244 (0.8%)	
Portal hypertension, *n* (%)	12/340 (3.5%)	2/96 (2.1%)	10/244 (4.1%)	0.365
Median tumour size, mm (i.q.r.)	36 (27–54)	35 (30–50)	37 (25–54)	0.777
Multiple tumours, *n* (%)	73/340 (21.5%)	16/96 (16.7%)	57/244 (23.4%)	0.176
Multiple resections, *n* (%)	25/340 (7.4%)	5/96 (5.2%)	20/244 (8.2%)	0.342
Concomitant operation non-cholecystectomy, *n* (%)	30/340 (8.8%)	5/96 (5.2%)	25/244 (10.2%)	0.140
Iwate score, *n* (%)				0.927
Intermediate	19/340 (5.6%)	6/96 (6.3%)	13/244 (5.3%)	
High	81/340 (23.8%)	22/96 (22.9%)	59/244 (24.2%)	
Expert	240 (70.6%)	68/96 (70.8%)	172/244 (70.5%)	

Bold represents statistically significant values.

Results

Three-hundred and forty patients met the study criteria, of whom 96 underwent R-RPS and 244 underwent L-RPS. The patients' clinicopathological features and perioperative outcomes are summarized in Tables 1 and 2. The median operating time was 295 minutes, and there were 25 (7.4 per cent) open conversions. Ninety-seven (28.5 per cent) patients had cirrhosis and 56 (16.5 per cent) patients required blood transfusion. The overall postoperative morbidity rate was 22.1 per cent and the major morbidity rate was 6.8 per cent. The median postoperative stay was 6 days.

Comparison between R-RPS and L-RPS in entire unmatched cohort

Before matching, the R-RPS group had a significantly greater proportion of patients with higher ASA score and cirrhosis (Table 1).

Table 2 Comparison between perioperative outcomes of R-RPS *versus* L-RPS

		Entire unmatched cohort		
	Total $n=340$	R-RPS $n=96$	L-RPS $n=244$	P
Median operating time (i.q.r.), min	295 (220–390)	271 (199–382)	311 (240–390)	**0.019**
Median blood loss (i.q.r.), ml	325 (150–700)	200 (100–500)	400 (200–800)	**< 0.001**
Blood loss (categories), ml				**< 0.001**
< 500 ml	193/318 (60.7%)	71/95 (74.7%)	122/223 (54.7%)	
≥ 500 ml	125/318 (39.3%)	24/95 (25.3%)	101/223 (45.3%)	
Intraoperative blood transfusion, *n* (%)	56/340 (16.5%)	11/96 (11.5%)	45/244 (18.4%)	0.118
Pringle manoeuvre applied, *n* (%)	209/339 (61.7%)	60/96 (62.5%)	149/243 (61.3%)	0.840
Median Pringle duration when applied (i.q.r.), min	45 (29–63)	40 (26–60)	45 (30–67)	0.171
Open conversion, *n* (%)	25/340 (7.4%)	2/96 (2.1%)	23/244 (9.4%)	**0.020**
Median postoperative stay, days (i.q.r.)	6 (5–8)	6 (5–8)	6 (5–8)	0.839
30-day readmission, *n* (%)	11/340 (3.2%)	4/96 (4.2%)	7/244 (2.9%)	0.543
Postoperative morbidity, *n* (%)	75/340 (22.1%)	23/96 (24.0%)	52/244 (21.3%)	0.596
Major morbidity (Clavien–Dindo grade > II), *n* (%)	23/340 (6.8%)	2/96 (2.1%)	21/244 (8.6%)	**0.031**
Reoperation, *n* (%)	2/340 (0.6%)	0/96 (0.0%)	2/244 (0.8%)	0.374
30-day mortality, *n* (%)	0/340 (0.0%)	0/96 (0.0%)	0/244 (0.0%)	n.e.
In-hospital mortality, *n* (%)	3/340 (0.9%)	0/96 (0.0%)	3/244 (1.2%)	0.275
90-day mortality, *n* (%)	5/340 (1.5%)	1/96 (1.0%)	4/244 (1.6%)	0.680
Close/involved margins (≤ 1 mm) for malignancies, *n* (%)	52/301 (12.4%)	11/89 (12.4%)	41/212 (19.3%)	0.144

n.e., not evaluable. Bold represents statistically significant values.

Table 3 Comparison between baseline clinicopathological characteristics of R-RPS *versus* L-RPS after propensity score matching

	1 : 2 propensity-matched cohort			1 : 1 propensity-matched cohort		
	R-RPS $n=66$	L-RPS $n=132$	P*	R-RPS $n=88$	L-RPS $n=88$	P*
Median age (i.q.r.), years	60 (51–70)	60 (52–69)	0.771	60 (51–69)	61 (54–69)	0.410
Male sex, *n* (%)	43/66 (65.2%)	87/131 (66.4%)	0.829	59/88 (67.0%)	64/88 (72.7%)	0.413
ASA score, *n* (%)			0.676			0.870
I	9/66 (13.6%)	19/130 (14.6%)		10/88 (11.4%)	9/87 (10.3%)	
II	36/66 (54.5%)	380/130 (61.5%)		42/88 (47.7%)	47/87 (54.0%)	
III	20/66 (30.3%)	30/130 (23.1%)		35/88 (39.8%)	30/87 (34.5%)	
IV	1/66 (1.5%)	1/130 (0.8%)		1/88 (1.1%)	1/87 (1.2%)	
Previous abdominal surgery, *n* (%)	20/66 (30.3%)	43/132 (32.6%)	0.744	27/88 (30.7%)	29/88 (33.0%)	0.724
Previous liver surgery, *n* (%)	1/66 (1.5%)	4/132 (3.0%)	0.525	2/88 (2.3%)	2/88 (2.3%)	1.000
Malignant pathology, *n* (%)	60/66 (90.9%)	121/132 (91.7%)	0.860	81/88 (92.0%)	83/88 (94.3%)	0.566
Pathology type, *n* (%)			0.871			0.914
HCC	36/66 (54.5%)	77/132 (58.3%)		52/88 (59.1%)	54/88 (61.4%)	
CRM	17/66 (25.8%)	32/132 (24.2%)		21/88 (23.9%)	21/88 (23.9%)	
Other	13/66 (19.7%)	23/132 (17.4%)		15/88 (17.0%)	13/88 (14.8%)	
Cirrhosis, *n* (%)	18/66 (27.3%)	45/132 (34.1%)	0.329	29/88 (33.0%)	32/88 (36.4%)	0.640
Child–Pugh score, *n* (%)			0.518			0.561
No cirrhosis	48/66 (72.7%)	87/132 (65.9%)		59/88 (67.0%)	56/88 (63.6%)	
A	18/66 (27.3%)	44/132 (33.3%)		29/88 (33.0%)	31/88 (35.2%)	
B	0/66 (0.0%)	1/132 (08%)		0/88 (0.0%)	1/88 (1.1%)	
Portal hypertension, *n* (%)	1/66 (1.5%)	2/132 (1.5%)	1.000	1/88 (1.1%)	2/88 (2.3%)	0.571
Median tumour size, mm (i.q.r.)	35 (28–50)	39 (29–54)	0.558	35 (30–50)	40 (30–52)	0.453
Multiple tumours, *n* (%)	15/66 (22.7%)	24/132 (18.2%)	0.481	16/88 (18.2%)	17/88 (19.3%)	0.853
Multiple resections, *n* (%)	5/66 (7.6%)	6/132 (4.6%)	0.405	5/88 (5.7%)	4/88 (4.5%)	0.739
Concomitant operation non-cholecystectomy, *n* (%)	4/66 (6.1%)	9/132 (6.8%)	0.831	5/88 (5.7%)	5/88 (5.7%)	1.000
Iwate score, *n* (%)			0.971			0.500
Intermediate	5/66 (7.6%)	10/132 (7.6%)		5/88 (5.7%)	2/88 (2.3%)	
High	14/66 (21.2%)	30/132 (22.7%)		21/88 (23.9%)	23/88 (26.1%)	
Expert	47/66 (71.2%)	92/132 (69.7%)		62/88 (70.4%)	63/88 (71.6%)	

*P-values were obtained from conditional logistic regression or mixed-effects quantile regression for binary and continuous variables, respectively. The respective marginal models were used when convergence could not be achieved.

Table 4 Comparison between perioperative outcomes of R-RPS *versus* L-RPS after propensity score matching

	1 : 2 propensity-matched cohort			1 : 1 propensity-matched cohort		
	R-RPS *n* = 66	L-RPS *n* = 132	P*	R-RPS *n* = 88	L-RPS *n* = 88	P*
Median operating time (i.q.r.), min	272 (217–397)	303 (240–390)	0.172	272 (196–397)	310 (243–405)	0.132
Median blood loss (i.q.r.), ml	200 (100–400)	450 (200–800)	**< 0.001**	200 (100–400)	450 (200–900)	**< 0.001**
Blood loss (categories), ml			**< 0.001**			**0.001**
< 500 ml	51/66 (77.3%)	63/124 (50.8%)		67/88 (76.1%)	44/86 (51.2%)	
≥ 500 ml	15/66 (22.7%)	61/124 (49.2%)		21/88 (23.9%)	42/86 (48.8%)	
Intraoperative blood transfusion, *n* (%)	6/66 (9.1%)	29/132 (22.0%)	**0.026**	9/88 (10.2%)	21/88 (23.9%)	**0.014**
Pringle manoeuvre applied, *n* (%)	39/66 (59.1%)	84/131 (64.1%)	0.489	55/88 (62.5%)	56/88 (63.6%)	0.882
Median Pringle duration when applied (i.q.r.) min	36 (25–54)	45 (30–70)	0.278	39 (26–60)	45 (34–75)	0.084
Open conversion, *n* (%)	2/66 (3.0%)	13/132 (9.8%)	**0.001**	2/88 (2.3%)	10/88 (11.4%)	**0.016**
Median postoperative stay, days (i.q.r.)	6 (4–8)	6 (5–8)	0.925	6 (5–8)	6 (5–9)	0.845
30-day readmission, *n* (%)	3/66 (4.5%)	3/132 (2.3%)	0.400	3/88 (3.4%)	3/88 (3.4%)	1.000
Postoperative morbidity, *n* (%)	16/66 (24.2%)	27/132 (20.5%)	0.512	22/88 (25.0%)	18/88 (20.5%)	0.451
Major morbidity (Clavien–Dindo grade > II), *n* (%)	1/66 (1.5%)	9/132 (6.8%)	0.113	2/88 (2.3%)	7/88 (8.0%)	0.118
Reoperation, *n* (%)	0/66 (0.0%)	1/132 (0.8%)	0.478	0/88 (0.0%)	0/88 (0.0%)	n.e.
30-day mortality, *n* (%)	0/66 (0.0%)	0/132 (0.0%)	n.e.	0/88 (0.0%)	0/88 (0.0%)	n.e.
In-hospital mortality, *n* (%)	0/66 (0.0%)	1/132 (0.8%)	n.e.	0/88 (0.0%)	1/88 (1.1%)	0.316
90-day mortality, *n* (%)	0/66 (0.0%)	2/132 (1.5%)	0.315	0/88 (0.0%)	1/88 (1.1%)	0.316
Close/involved margins (≤ 1 mm) for malignancies, *n* (%)	9/60 (15.0%)	21/121 (17.4%)	0.595	11/81 (13.6%)	15/83 (18.1%)	0.655

*P-values were obtained from conditional logistic regression or mixed-effects quantile regression for binary and continuous variables, respectively. The respective marginal models were used when convergence could not be achieved. n.e., not evaluable. Bold represents statistically significant values.

The median operating time was significantly longer for the robotic group, with reduced median blood loss and lower proportion of patients with blood loss of > 500 ml. Open conversion was significantly lower in the robotic group (2.1 *versus* 9.4 per cent), with a lower rate of major morbidity (Clavien–Dindo grade > II). The remaining perioperative, intraoperative, and postoperative parameters were not significantly different between the groups. Oncological outcomes such as close/involved margins were similar between the groups (*Table 2*).

Comparison between R-RPS and L-RPS in matched cohorts

In the propensity-matched cohorts, the parameters of cirrhosis and ASA score were well matched in both the 1 : 1 and 2 : 1 cohorts (*Table 3*). Median blood loss, frequency of major blood loss (> 500 ml), need for intraoperative blood transfusion, and open conversion rate remained significantly lower with R-RPS, compared with L-RPS (*Table 4*). The median operating time and major morbidity rate did not differ significantly after PSM. There was no statistically significant difference in 30-day, 90-day, and inpatient mortality rates and the rate of close/involved margins.

Discussion

Previous studies have established the role of laparoscopic hepatectomy[33–38]. Similar to conventional laparoscopy, RH has been reported to be associated with shorter hospital stay, lower cost, and fewer complications compared with open hepatectomy, albeit with longer operating times[39,40].

A recent updated meta-analysis found less blood loss and lower readmission rates but longer operating time for the robotic group. There were, however, no significant differences in the rates of overall complication, length of stay, conversion, and transfusion[41]. Similarly, an American College of Surgeons-National Surgical Quality Improvement Program (ACS-NSQIP) database review of 3152 MIH and 480 open surgery procedures were analysed. The robotic group comprising 240 patients showed longer operating times, but lower rates of open conversion after 1 : 1 matching with the laparoscopic group. Significantly, laparoscopic resection with unplanned conversion was associated with increased morbidity. However, in this analysis, the proportion of major hepatectomy was only 13–14 per cent[42].

A recent systematic review of robotic *versus* laparoscopic major hepatectomies involving 525 patients (300 laparoscopic *versus* 225 robotic) showed no significant differences regarding rates of overall complications, severe complications, and overall mortality. Perioperative parameters of blood loss, operating time, and length of stay, as well as conversion to open and transfusion rates, also were not significantly different[43]. These results suggest that for more complex operations, the robotic platform was at least equivalent in outcomes to the laparoscopic approach.

The difficulty of resection in the posterosuperior segments in MIH has been well documented[16]. Many studies showed increased operating times, longer hospital stays, higher rates of conversions, and increased blood loss, compared with resections in the anterolateral segments for laparoscopy[44,45]. Robotic assistance has been touted as a viable alternative without use of the thoracic–diaphragmatic approach or intercostal space approaches. The largest robotic series of 100 patients who underwent resection of lesions from the posterosuperior segments from a single centre showed nil conversions and 100 per cent R0 resection rate, with median blood losses of 100 ml and 50 ml for subsegmentectomy/segmentectomies and partial hepatectomies, respectively[46].

Anatomical RPS is generally considered challenging via laparoscopy, even for experienced laparoscopic HPB surgeons. The transection area is wider than for a formal right hepatectomy, and horizontal. Identification and isolation of the right posterior pedicle can be challenging, leading to a variable approach to its control for obtaining a demarcation line before parenchymal transection. The RHV does not always run in the intersectional plane, particularly in the inferior (caudal) area[47]. Furthermore, the RHV usually has several thin-walled tributaries that are easily torn by the inexperienced surgeon, either by retraction or through injuries from inadequate cutting plane exposure, injudicious use of energy device, or poor cavitron ultrasonic surgical aspirator (CUSA) technique. A detailed understanding of the preoperative anatomy of the inflow and RHV course, combined with a detailed study of the RHV, may go some way to mitigating the risk of potential catastrophic bleeding. Most laparoscopic surgeons would consider positioning the patient in the left lateral decubitus, reverse Trendelenburg position to elevate the cutting plane to a more vertical direction, while increasing drainage of the RHV down into the inferior vena cava (IVC)[48]. Multiple techniques have been proposed with a vein-based approach, including the peripheral-to-root caudal approach and the root-to-peripheral approaches[49]. This is coupled with a technique described as a back-scoring technique with CUSA to avoid split or pulled-up injuries of the hepatic vein, which may be employed to increase the success of this procedure[50]. In the robotic technique, the positioning of the patient essentially mirrors that in the laparoscopic approach. Parenchymal transection is performed generally via either bipolar Maryland forceps or a harmonic scalpel clamp crush technique, or by use of harmonics by use of the harmonic scalpel with the jaws open, thus deploying the active jaw in a manner resembling the CUSA, which is not available for the robotic platform[16,51]. In some centres, laparoscopic CUSA is used concurrently to overcome this limitation[52].

In modern series, use of intravenous ICG as negative staining after pedicle control has been deployed in many expert centres to further guide precise anatomical resection both in laparoscopic surgery and in the robotic technique with Firefly[53]. Despite all these technical advancements, a tumour measuring >3 cm requiring L-RPS is considered a surgical procedure reserved for the expert surgeon, according to the Iwate criteria. While some would consider performing a right hemihepatectomy as a simpler procedure, this goes against the principle of parenchymal preservation and increases the risk of morbidity and mortality associated with the operation. In addition, it may not be possible to safely perform a right hepatectomy due to lack of future liver remnant volume or limited ICG clearance (R15) in certain cases of cirrhosis and hepatocellular carcinoma. It is important to emphasize that if RPS is technically possible but not feasible via a minimally invasive approach, it is preferred for the surgeon to perform the appropriate procedure via the open approach, rather than by carrying out a bigger procedure such as right hepatectomy via the minimally invasive approach.

This study had limitations by including multiple centres with a different range of experience in both laparoscopic and robotic resections, each with their own approach and surgical technique. As with all retrospective analysis, there will inevitably be a potential for information bias and selection bias although attempts to mitigate this with propensity scoring in both 1 : 1 and 1 : 2 showed no significant difference in results. It is important to add that apparent advantages associated with R-RPS may not be attributable to the robotic platform. Confounding factors such as individual surgeon experience and selection bias likely could have accounted for some of the observations. Moreover, it is possible that surgeons adopted a more selective criteria when choosing to perform R-RPS due to the higher costs and need to satisfy the increase in patient expectations. The main advantages of R-RPS over L-RPS seem to be lower open conversion rates and reduced blood loss, and this should reduce morbidity risks[54,55].

Collaborators

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Supplementary material

Supplementary material is available at *BJS* online.

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