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Propensity score-matching analysis comparing robotic versus laparoscopic limited liver resections of the posterosuperior segments: an international multi-center study

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Key points

This international multicenter PSM study demonstrated that RMLR for posterosuperior segments was associated with superior perioperative outcomes in terms of operative time, blood loss and open conversion rate when compared to LMLR, with a similar short term post operative safety profile

Abstract

Objective: To compare the outcomes of robotic limited liver resections (RLLR) versus laparoscopic limited liver resections (LLLR) of the posterosuperior segments.

Background: Both laparoscopic and robotic liver resections have been used for tumors in the posterosuperior liver segments. However, the comparative performance and safety of both approaches have not been well examined in existing literature.

Methods: This is a post hoc analysis of a multicenter database of 5,446 patients who underwent RLLR or LLLR of the posterosuperior segments (I, IVa, VII and VIII) at 60 international centers between 2008 and 2021. Data on baseline demographics, center experience and volume, tumour features and perioperative characteristics were collected and analysed. Propensity score matching (PSM) analysis (in both 1:1 and 1:2 ratios) was performed to minimize selection bias.

Results: A total of 3510 cases met the study criteria, of whom 3049 underwent LLLR (87%) and 461 underwent RLLR (13%). After PSM (1:1: and 1:2), RLLR was associated with a lower open conversion rate (10 of 449 [2.2%] vs. 54 of 898 [6.0%]; p=0.002), less blood loss (100ml [IQR; 50-200] days vs. 150ml [IQR; 50-350]; p<0.001) and a shorter operative time (188min [IQR; 140-270] vs. 222min [IQR; 158-300]; p<0.001). These improved perioperative outcomes associated with RLLR were similarly seen in a subset analysis of patients with cirrhosis - lower open conversion rate (1 of 136 [0.7%] vs. 17 of 272 [6.2%]; p=0.009), less blood loss (100ml [IQR; 48-200] vs. 160ml [IQR; 50-400]; p<0.001) and shorter operative time (190min [IQR; 141-258] vs. 230min [IQR; 160-312]; p=0.003). Post-operative outcomes in terms of readmission, morbidity and mortality were similar between RLLR and LLLR in both the overall PSM cohort and cirrhosis patient subset.

Conclusion: RLLR for the posterosuperior segments was associated with superior perioperative outcomes in terms of decreased operative time, blood loss and open conversion rate when compared to LLLR.

Key words: Laparoscopic liver resection; Robotic liver resection; Posterosuperior liver segments; Liver cirrhosis; minimally-invasive hepatectomy

Introduction

Minimally invasive liver resection (MILR) has been increasingly adopted worldwide since its inception in 1991, with several perioperative benefits over the conventional open approach.[1–3] However, MILR of the posterosuperior segments remain complex and challenging even in the hands of experienced liver surgeons.[4,5] As reflected by the Iwate criteria, such resections are associated with increased complexity and increased post operative complications.[6–8] The difficulty in performing posterosuperior resections is attributable to a limited working space even with pneumoperitoneum, hindered instrument access by the overlying rib cage and natural curvature of the liver dome even after adequate liver mobilization, and proximity to major venous structures.[7] In spite of these inherent technical difficulties, published experience from expert centers have demonstrated both the safety and potential benefits of MILR over the open approach for posterosuperior segments.[4,9,10]

Robotic surgery holds the potential for retaining the perioperative benefits MILR has to offer over the open approach, while offering to alleviate many of the technical challenges of conventional laparoscopy through innovation in surgical instrumentation.[11] With optimization of the operating environment through improved three-dimensional visualisation, superior instrument dexterity, stability and elimination of fatiguability, robotic liver resection has been found to be associated with a shorter learning curve as compared to laparoscopic liver resection.[12,13]

Potential benefits of a robotic approach in MILR have been examined in several published registry analyses by our international study group.[11,14] A recent study comparing robotic versus laparoscopic right hepatectomy and extended right hepatectomy found the robotic approach to be associated with a lower open conversion rate and shorter post operative hospital stay.[15] A lower open conversion rate associated with the robotic approach in MILR was similarly reported in another analysis of more than 3000 patients who underwent MILR of the anterolateral liver segments at 26 international centres.[16] In addressing the comparative performance of robotic and laparoscopic liver resections in the posterosuperior segments, we previously reported in a smaller study decreased blood loss, operating duration and open conversion rates in the robotic group in an analysis which included MILR of segments VII, VIII, and IVa.[17]. Notably, resections of segment I was excluded from the analysis, and the differential learning curves of participating surgical centers was not considered.

The primary objective of the current study was to compare the surgical outcomes of robotic limited liver resections (RLLR) versus laparoscopic limited liver resections (LLLR) for tumors in the posterosuperior segments with consideration of the case volume and experience of the participating surgical centers. The secondary objective was to compare the surgical outcomes of the subset of patients with cirrhosis in whom the technical challenges of MILR are potentially amplified.[18-21]

Methods

This is an international multicenter post hoc analysis of patients who underwent LLLR or RLLR for tumors in the posterosuperior segments (I, IVa, VII, VIII) at 60 centers between 2008 and 2021. All institutions of the International Robotic and Laparoscopic Liver Resection Study Group Investigators obtained their respective ethical approvals according to their local center requirements. This study was approved by the Institutional Review Board of Singapore General Hospital, with the need for patient consent waived as anonymized data was analyzed retrospectively. De-identified data was collected at the individual centers, then subsequently collated and analyzed centrally at the Singapore General Hospital.

There were 5,446 patients who underwent totally robotic or laparoscopic hepatectomies. Notably, laparoscopically assisted and hand-assisted laparoscopic resections were excluded. Additional exclusion criteria were patients with previous liver resections, patients undergoing multiple simultaneous liver resections in different segments and/or concomitant major operations (bilio-enteric anastomosis, portal vein ligation, colectomy, stoma reversal, bile duct exploration, gastrectomy, hilar lymph node dissection and splenectomy). Notably, patients with only concomitant minor surgeries such as hernia repairs and ablations were included.

Definitions

Liver resections were classified according to the 2000 Brisbane classification.[22] The posterosuperior segments included segments I, IVa, VII and VIII.[23] Limited liver resections were classified as wedge resections or segmentectomies. Both conventional major hepatectomies (resection of 3 or more segments) and technical major hepatectomies (right anterior and right posterior sectionectomies) as previously defined were excluded.[24] The recently proposed "New World" terminology for liver resections was not used as this definition was not recorded in most center's prospective databases.[25]

All robotic resections were performed using the different versions (mainly Xi and Si) of the Da Vinci robotic platform (Intuitive Surgical, Sunnyvale, CA, USA). Operation time was time from skin incision to skin closure. Clinically significant portal hypertension was defined based on radiological and clinical criteria such as the presence of ascites, esophageal varices or splenomegaly with a platelet count of less than 100,000/μL (portal venous pressure/hepatic venous pressure gradient was not routinely measured in most centers). Post-operative complications were classified according to the Clavien-Dindo classification and recorded for up to 30 days or during the same hospitalization and included 30-day readmissions.[26] The difficulty of resections was graded according to the Iwate criteria[6,27] and

Institute Mutualiste Montsouris (IMM) classification system.[23] Diameter of the largest lesion was used in cases of multiple tumors.

In order to mitigate confounding factors from historical bias and center experience, the resections were classified into 3 periods: 2008-2012, 2013-2017 and 2018-2021. Each individual center's average annual case volume for MILR during each of the 3 periods was also recorded and used to categorise centers into three groups: <20 cases/year, 20-75 cases/year, and >75 cases per year. In addition, whether each centre had a cumulative experience of ≤50 cases of MILR or not was recorded as a reflection of a center's progress in mounting the MILR learning curve as previously defined.[12]

Statistical analysis

Propensity-score matching (PSM) was performed using a 1:1 and a 1.2 nearest neighbour matching algorithm without replacement with distances determined by logistic regression. PSM was performed based on all variables shown in Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/SLA/E765. The optimal matching algorithm was utilized as a sensitivity analysis. Cases performed within a center's learning curve defined as the first 50 cases were included in the matching. The number of 50 cases was chosen based on the recently published systematic review, which reported that the overall learning curve for LLR was 50 cases (range 25-58) and for RLR was 25 cases 16-50.[12] PSM was performed based on the following variables: gender, year of resection, center's annual case volume, cases performed during the learning curve (first 50 cases), age at operation, American Society of Anesthesiologists (ASA) status, size of tumour, single or multiple tumours, malignant or benign tumours, cirrhosis with Child Pugh score, presence of portal hypertension, previous liver surgery, previous open liver surgery, previous abdominal operation, concomitant minor non-cholecystectomy operation, hilar lymph node dissection, histological diagnosis, Iwate difficulty grade and IMM procedure code.

Covariate distributions between patients undergoing robotic or laparoscopic liver resections were found to be balanced after conditioning on the propensity score, where a difference of <0.1 in absolute standard mean difference after matching was considered to indicate a good balance.

In the unmatched cohort, comparisons of patient characteristics, and peri- and post-operative details between patients were performed using Mann-Whitney U test for continuous variables, while Fisher's exact test and Pearson's $\chi 2$ test were used for categorical variables. Comparisons in the matched cohorts took into account the paired nature of the data; hence, paired analyses such as Wilcoxon signed-rank test, McNemar test and McNemar-Bowker test. All analyses were done in R-4.0.0 with package 'MatchIt' and 'optmatch', and $P < 0.05$ were regarded to indicate statistical significance.

Results

Baseline characteristics in the unmatched cohorts

A total of 3510 cases met the inclusion criteria of the study of which 3049 (86.9%) underwent LLLR and 461 (13.1%) underwent RMLR. Baseline characteristics of the unmatched cohorts are shown in Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/SLA/E765. Prior to matching, patients who underwent RLLR had a younger median age (61 [IQR: 49-68] vs 63 [IQR: 53-71]; p<0.001), higher American Society of Anaesthesiology (ASA) scores (ASA score of III/IV in 37.5% vs 26.5%; p<0.001), lower proportion of patients with liver cirrhosis (30.6% vs 39.4%; p<0.001) and a larger median tumor size (30cm [IQR: 20-45] vs 26cm [IQR: 18-40]; p<0.001). In terms of case volume and center experience, there was a greater proportion of RLLR cases performed in low volume (average annual volume <25 cases) centers (15.4% vs 7.5%; p<0.001), and in centers with a cumulative experience of ≤50 MILR cases (10.2% vs 4.2%; p<0.001).

Comparison between LLLR and RLLR in the matched cohorts

Following a 1:1 PSM, 449 cases of RLLR were matched to 449 cases of LLLR. Following a 1:2 PSM, 449 cases of RLLR were matched to 898 cases of LLLR. Both groups were well balanced in baseline demographics, clinicopathologic characteristics and center volume/experience following PSM in both 1:1 and 1:2 cohorts as shown in Supplemental Table 1, Supplemental Digital Content 1, http://links.lww.com/SLA/E765, Supplemental Figure 1, Supplemental Digital Content 1, http://links.lww.com/SLA/E765.

The perioperative outcomes in the matched cohort are summarised in **Table 1**. Notably, in the 1:2 PSM cohort, RLLR was associated with a shorter median operating time (188min [IQR:140-270] vs 222min [IQR: 158-300]; p<0.001) and lower open conversion rate (2.2% vs 6.0%; p=0.002). Additionally, RLLR was associated with a lower median blood loss (100ml [IQR: 50-200] vs 150ml [IQR:50-350]; p<0.001), with less frequent application of the Pringle maneuver (45.3% vs 54.7%; p=0.001). Post operatively, RLLR was associated with a shorter median length of stay (5 days [IQR: 3-6] vs 5 days [IQR: 4-8], with no significant difference between both groups in terms of post operative morbidity, mortality, reoperation and 30-day readmission. These associations were consistently seen in the 1:1 PSM cohort as well.

Comparison between LLLR and RLLR in the subset of patients with cirrhosis

A subset analysis for the 1343 patients with cirrhosis was performed, in which a 1:1 PSM matched 136 LLLR cases to 136 RLLR cases, and a 1:2 PSM matched 136 RLLR cases to 272 LMLR cases. The baseline characteristics of the unmatched and matched (both 1:1 and 1:2 PSM) cohorts of patients with cirrhosis are summarised in Supplemental Table 2, Supplemental Digital Content 1, http://links.lww.com/SLA/E765. Prior to matching, patients who underwent RLLR had a higher ASA score (ASA score of III/IV in 40.4% vs 30.9%; p=0.021), and a greater proportion of cases performed in low volume (average annual volume <25 cases) centers (18.2% vs 8.7%; p<0.001) and in centers with a cumulative experience of ≤50 MILR cases (9.9% vs 4.6%; p=0.006). After PSM (1:1 and 1:2), the baseline characteristics of patients with liver cirrhosis were well balanced (Supplemental Figure 2, Supplemental Digital Content 1, http://links.lww.com/SLA/E765).

The perioperative outcomes in the subset of patients with cirrhosis are summarised in **Table 2**. Notably, in the 1:2 PSM cohort, RLLR was associated with a shorter median operating time (190min [IQR: 141-258] vs 230min [IQR: 160-312]; p=0.003), lower open conversion rate (0.7% vs 6.2%; p=0.009), lower median blood loss (100ml [IQR: 48-200] vs 160ml [IQR: 50-400]; p<0.001), and a shorter median post operative stay (5 days [IQR: 3-6] vs 6 days [IQR: 4-8]; p=0.011). There was no significant difference between both groups in terms of post operative morbidity, mortality, reoperation and 30-day readmission. These associations were consistently seen in the 1:1 PSM cohort as well.

Comparison between LLLR and RLLR in the subset of patients with wedge resections or segmentectomies

In the subset of patients undergoing wedge resections, after 1:1 PSM, RLLR was associated with significantly shorter operation time, blood loss, use of the Pringles manoeuvre, open conversion rate and postoperative length of stay **(**Supplemental Table 3 and 4, Supplemental Digital Content 1, http://links.lww.com/SLA/E765**)**. Similarly, in the subset of patients undergoing segmentectomies alone, after 1:1 PSM, RLLR was associated with significantly shorter operation time, blood loss, use of the Pringles manoeuvre, open conversion rate and postoperative length of stay (Supplemental Table 5 and 6, Supplemental Digital Content 1, http://links.lww.com/SLA/E765).

Discussion

This international, multicenter study demonstrated that RLLR, as compared to LLLR for posterosuperior segments, is associated with several perioperative advantages including a shorter operative time, decreased blood loss, and a lower likelihood of open conversion, with a similar post operative safety profile. Notably, these perioperative benefits appear to be more pronounced in patients with liver cirrhosis, who are more likely to have post operative complications following liver resection.[28]

Surgical resection of the posterosuperior liver segments has conventionally posed a significant challenge due to the relative inaccessibility and proximity to major vascular structures.[4,5,29] An open approach necessitates a large incision for adequate exposure and mobilisation, which often becomes the key variable in determining the post operative recovery of the patient for an otherwise minor liver resection.[30] MILR negates the use of extensive surgical incisions, with the trade-off of a significantly more technically challenging procedure. The inherent difficulty of performing MILR for the posterosuperior segments is reflected by various consensus statements and MILR difficulty scoring systems.[2,6,8,31] Additionally, several comparative studies have reported worse perioperative outcomes in MILR of the posterosuperior segments as compared to anterolateral segments.[29,32] Robotic surgery has several theoretical advantages over conventional laparoscopic surgery including improved three-dimensional visualisation, superior instrument dexterity, stability and elimination of fatiguability.[33,34] However, existing data on the comparative performance of robotic and laparoscopic liver resections in the posterosuperior segments is heterogeneous, limited by a lack of specific anatomic inclusion criteria, small cohort sizes and a lack of correction for key confounders such as center volume and experience.[35-39] The use of intercostal or transthoracic ports have been recommended by some centers to overcome the ergonomic limitations of rigid laparoscopic instruments and facilitate resections of the superior segments. However, this in turn may result in additional complications such as pneumothorax and pleural effusion. Proponents of robotic liver resections have cited the advantage of the articulating arms of the robotic platform enabling resections of these segments without the use of transthoracic ports. Unfortunately, detailed information on port placement was not available in this study and this could not be analyzed.

The superior intraoperative outcomes reported in our study may be attributable to the improved technical performance afforded by robotic platform for tumors in the posterosuperior segments. These benefits are likely in part interrelated, with improved dissection and hemostasis capabilities resulting in lower blood loss, decreased need for application of Pringle's maneuver, shorter operative duration and lower rates of open conversion. This is in contrast with a previous PSM cohort study of 36 robotic versus 72 laparoscopic liver resections of the posterosuperior segments which reported similar blood loss in both groups, but a significantly longer inflow occlusion time in the robotic group.[39] Notably, this was a bi-institutional study with a limited sample size, which utilised a PSM analysis which did not account for center volume/experience. The perioperative benefits reported in our study were similarly seen in the subset of patients with cirrhosis, for whom such benefits are likely to be of greater clinical relevance as even minor complications can be lethal.[18-21]

A major factor influencing the perioperative outcomes of different approaches in MILR is the relative procedural experience of the center. This is especially for resections of the posterosuperior segments which has consistently been recommended to be performed only in highly experienced.[31] Not unexpectedly, there was a temporal evolution in the performance of MILR for the posterosuperior segments in our study cohort, with an increasing proportion of cases performed over time from 281 cases in 2008-2012 (5-year period) to 1419 cases in 2013-2017 (5-year period) and 1810 cases in 2018-2021 (4-year period). In the unmatched cohort, there was a greater proportion of RLLR performed in centers with lower annual case volume and cumulative experience. This observation suggests that RLLR may possibly be associated with a shorter learning curve and hence is preferred by lower volume centers.[12] Importantly, these centers were likely to be still in the process of mounting their respective MILR learning curves. Hence, the importance of adjusting for center volume and experience as a baseline covariate as we did in this current updated analysis of our previous study when comparing between RLLR and LLLR in posterosuperior segments to account for the effect of the inherent learning curve on perioperative outcomes.[17] Additionally, there was a significant proportion of patients who had previous abdominal surgery (over a third of patients in both groups) which highlights the technical feasibility and safety profile of MILR in these patients, which has similarly been reported previously.[15,40,41,42]

A key limitation of this study is the retrospective nature of the data collection, with its attendant issues of selection bias in assigning patients between both groups. The utilization of a PSM analysis sought to mitigate this by controlling for known important confounders, of which a comprehensive and robust set of covariates (including center volume and experience) was included in our study. Notably, the granularity of possible learning curve effects on outcomes could not be determined at the individual surgeon level, which could have introduced potential bias as surgeons who performed robotic resections may be more experienced (having undergone a pre-existing period of laparoscopic training) for which the barriers to entry (in terms of cost and logistical availability) are much higher than laparoscopic resections. Another limitation is the substantial variation in case selection, perioperative practices and surgical technique inherent in this international multicenter retrospective registry study, which may give rise to biases which PSM cannot fully account for. This however potentially improves the generalizability of our study's findings and reflect potential comparative benefits of RLLR over LLLR despite inter-institutional heterogeneity.

Conclusion

This international multicenter PSM study demonstrated that RLLR for posterosuperior segments was associated with superior perioperative outcomes in terms of operative time, blood loss and open conversion rate when compared to LLLR, with a similar short term postoperative safety profile.

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Declarations

We confirm all the authors are accountable for all aspects of the work

i) Dr Goh BK has received travel grants and honorarium from Johnson and Johnson and Olympus.

ii) Dr Marino MV is a consultant for CAVA robotics LLC.

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Table 1. Comparison between perioperative outcomes of robotic minor liver resections (RMLR) vs laparoscopic minor liver resections (LMLR).

Table 2. Comparison between perioperative outcomes of robotic minor liver resections (RMLR) vs laparoscopic minor liver resections (LMLR) in subset of 1343 patients with cirrhosis.

Table 1. Comparison between perioperative outcomes of robotic minor liver resections (RMLR) vs laparoscopic minor liver resections (LMLR). Interquartile range (IQR).

		Unmatched cohort			1:1 Propensity score matching (nearest neighbor matching)			1:2 Propensity score matching (nearest neighbor matching)		
	level	LMLR	RMLR	p-value	LMLR	RMLR	p-value	LMLR	RMLR	p-value
N		3049	461		449	449		898	449	
Operating time (median [IQR])		210.00 [150.00, 291.25]	188.50 [140.00, 271.25]	**0.001**	225.00 [160.00, 303.75]	188.00 [140.00, 270.00]	**<0.001**	222.00 [158.00, 300.00]	188.00 [140.00, 270.00]	**<0.001**
Blood loss, ml (median [IQR])		150.00 [50.00, 350.00]	100.00 [50.00, 200.00]	**<0.001**	163.00 [50.00, 300.00]	100.00 [50.00, 200.00]	**<0.001**	150.00 [50.00, 350.00]	100.00 [50.00, 200.00]	**<0.001**
Blood loss (categories) (%)	<500	2649 (86.9)	396 (85.9)	0.563	394 (87.8)	384 (85.5)	0.363	766 (85.3)	384 (85.5)	0.913
	>=500	400 (13.1)	65 (14.1)		55 (12.2)	65 (14.5)		132 (14.7)	65 (14.5)	
Intraoperative blood transfusion (%)	Yes	286 (9.4)	30 (6.5)	**0.045**	41 (9.1)	28 (6.2)	0.143	76 (8.5)	28 (6.2)	0.152
Pringle maneuver applied (%)	Yes	1558 (52.8)	209 (45.4)	**0.003**	232 (52.7)	203 (45.3)	**0.033**	480 (54.7)	203 (45.3)	**0.001**

Open conversion (%)	Yes	171 (5.6)	10 (2.2)	**0.002**	23 (5.1)	10 (2.2)	**0.031**	54 (6.0)	10 (2.2)	**0.002**
Post operative stay, days (median [IQR])		5.00 [4.00, 8.00]	5.00 [3.00, 6.00]	**<0.001**	5.00 [4.00, 8.00]	5.00 [3.00, 6.00]	**<0.001**	5.00 [4.00, 8.00]	5.00 [3.00, 6.00]	**<0.001**
30-day readmission (%)	Yes	85 (2.8)	11 (2.4)	0.621	13 (2.9)	11 (2.4)	0.838	31 (3.5)	11 (2.4)	0.318
Post operative morbidity (%)	Yes	538 (17.7)	93 (20.2)	0.189	74 (16.5)	91 (20.3)	0.165	154 (17.1)	91 (20.3)	0.162
Major morbidity (Clavien-Dindo grade> 2) (%)	Yes	159 (5.2)	28 (6.1)	0.446	23 (5.1)	27 (6.0)	0.671	53 (5.9)	27 (6.0)	0.935
Reoperation (%)	Yes	25 (0.8)	3 (0.7)	1.000	4 (0.9)	3 (0.7)	1.000	8 (0.9)	3 (0.7)	0.761
30-day mortality (%)	Yes	7 (0.2)	1 (0.2)	1.000	1 (0.2)	1 (0.2)	1.000	4 (0.4)	1 (0.2)	0.670
In-hospital mortality (%)	Yes	13 (0.4)	1 (0.2)	1.000	1 (0.2)	1 (0.2)	1.000	6 (0.7)	1 (0.2)	0.435
90-day mortality (%)	Yes	13 (0.4)	1 (0.2)	1.000	2 (0.4)	1 (0.2)	1.000	5 (0.6)	1 (0.2)	0.670

Table 2. Comparison between perioperative outcomes of robotic minor liver resections (RMLR) vs laparoscopic minor liver resections (LMLR) in subset of 1343 patients with cirrhosis. Interquartile range (IQR).

		Unmatched cohort			1:1 Propensity score matching (nearest neighbor matching)			1:2 Propensity score matching (nearest neighbor matching)		
	level	LMLR	RMLR	p	LMLR	RMLR	p	LMLR	RMLR	p
n		1202	141		136	136		272	136	
Operating time (median [IQR])		225.00 [169.75, 300.00]	196.50 [143.25, 271.25]	**0.001**	238.00 [164.75, 341.00]	190.00 [140.50, 258.00]	**0.005**	230.00 [160.00, 311.50]	190.00 [140.50, 258.00]	**0.003**
Blood loss, ml (median [IQR])		200.00 [50.00, 400.00]	100.00 [50.00, 200.00]	**<0.001**	200.00 [100.00, 400.00]	100.00 [47.50, 200.00]	**<0.001**	160.00 [50.00, 400.00]	100.00 [47.50, 200.00]	**<0.001**
Blood loss (categories) (%)	<500	1033 (85.9)	122 (86.5)	0.850	111 (81.6)	117 (86.0)	0.417	227 (83.5)	117 (86.0)	0.500
	>=500	169 (14.1)	19 (13.5)		25 (18.4)	19 (14.0)		45 (16.5)	19 (14.0)	
Intraoperative blood transfusion (%)	Yes	150 (12.5)	9 (6.4)	**0.034**	11 (8.1)	8 (5.9)	0.628	25 (9.2)	8 (5.9)	0.248
Pringle maneuver applied (%)	Yes	681 (57.6)	67 (47.5)	**0.022**	80 (60.2)	63 (46.3)	0.065	149 (56.2)	63 (46.3)	0.060

Open conversion (%)	Yes	65 (5.4)	1 (0.7)	**0.011**	10 (7.4)	1 (0.7)	**0.008**	17 (6.2)	1 (0.7)	**0.009**
Post operative stay, days (median [IQR])		6.00 [5.00, 10.00]	5.00 [3.00, 7.00]	**<0.001**	6.00 [4.00, 9.00]	5.00 [3.00, 6.25]	**0.026**	6.00 [4.00, 8.00]	5.00 [3.00, 6.25]	**0.011**
30-day readmission (%)	Yes	31 (2.6)	6 (4.3)	0.250	4 (2.9)	6 (4.4)	0.752	8 (2.9)	6 (4.4)	0.442
Post operative morbidity (%)	Yes	237 (19.7)	29 (20.6)	0.811	28 (20.6)	29 (21.3)	1.000	55 (20.2)	29 (21.3)	0.795
Major morbidity (Clavien-Dindo grade> 2) (%)	Yes	60 (5.0)	11 (7.8)	0.158	7 (5.1)	11 (8.1)	0.453	13 (4.8)	11 (8.1)	0.181
Reoperation (%)	Yes	6 (0.5)	2 (1.4)	0.202	1 (0.7)	2 (1.5)	1.000	2 (0.7)	2 (1.5)	0.603
30-day mortality (%)	Yes	1 (0.1)	1 (0.7)	0.199	0 (0.0)	1 (0.7)	1.000	0 (0.0)	1 (0.7)	0.333
In-hospital mortality (%)	Yes	4 (0.3)	1 (0.7)	0.426	0 (0.0)	1 (0.7)	1.000	0 (0.0)	1 (0.7)	0.333
90-day mortality (%)	Yes	4 (0.3)	1 (0.7)	0.426	0 (0.0)	1 (0.7)	1.000	0 (0.0)	1 (0.7)	0.333