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Impact of body mass index on the difficulty and outcomes of laparoscopic left lateral sectionectomy.

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Abstract

Introduction: Currently, the impact of body mass index (BMI) on the outcomes of laparoscopic liver resections (LLR) is poorly defined. This study attempts to evaluate the impact of BMI on the peri-operative outcomes following laparoscopic left lateral sectionectomy (L-LLS).

Methods: A retrospective analysis of 2183 patients who underwent pure L-LLS at 59 international centers between 2004 and 2021 was performed. Associations between BMI and selected peri-operative outcomes were analyzed using restricted cubic splines.

Results: A BMI of >27kg/m2 was associated with increased in blood loss (Mean difference (MD) 21mls, 95% CI 5 – 36), open conversions (Relative risk (RR) 1.13, 95% CI 1.03 – 1.25), operative time (MD 11 minutes, 95% CI 6–16), use of Pringles maneuver (RR 1.15, 95% CI 1.06−1.26) and reductions in length of stay (MD −0.2 days, 95% CI −0.3 to −0.1). The magnitude of these differences increased with each unit increase in BMI. However, there was a “U” shaped association between BMI and morbidity with the highest complication rates observed in underweight and obese patients.

Conclusion: Increasing BMI resulted in increasing difficulty of L-LLS. Consideration should be given to its incorporation in future difficulty scoring systems in laparoscopic liver resections.

Keywords

laparoscopic liver; laparoscopic hepatectomy; minimally-invasive liver; minimally-invasive hepatectomy; body mass index; left lateral sectionectomy

Introduction

The adoption of laparoscopic liver resection (LLR) is steadily gaining global acceptance given its advantages of reduced blood loss, lower morbidity and faster recovery as compared to open liver resection (OLR) (1, 2). However, universal adoption is hampered by its steep

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learning curve, particularly for major hepatectomies or resections involving difficult postero-superior segments (3–7). In the 2nd International Consensus Conference on Laparoscopic Liver Resection held in Morioka, Japan, the experts stated the importance of the difficulty scoring systems (DSS) to predict the surgical difficulty of LLR, which guides patient selection according to the surgeon's surgical experience and technical ability (8). Since then, several DSSs have been established, including the Iwate score (9), Southampton scoring system (10) and the Institut Mutualiste Montsouris (IMM) (11, 12).

One of the inherent drawbacks of the current DSSs is that it does not account for other variables which potentially influence difficulty in LLR. Obesity, a global health pandemic, has been associated with numerous co-morbidities, including non-alcoholic fatty liver disease (NAFLD), non-alcoholic steatohepatitis (NASH), and liver cirrhosis (13). Recently, anthropometric measures such as Body Mass Index (BMI) have been found to influence peri-operative outcomes in LLR (14), however, such studies included all extents of liver resections and not specific types. It is likely that patient BMI may influence outcomes after LLR to differing extents depending on the type and extent of liver resection.

Amongst the different types of LLR, laparoscopic left lateral sectionectomy (L-LLS) is perhaps the more widely performed procedure. The left lateral lobe has several anatomic advantages, which render it amenable to LLR. Its proximity to the abdominal wall, ease of mobilization, and relatively consistent intra-hepatic biliovascular anatomy allows for a shorter learning curve. For these reasons, L-LLS has a generally lower difficulty score among DSS categories and has been advocated as a standard of care for all left lateral lobe lesions of the liver (15). Given the paucity of evidence evaluating the impact of BMI on L-LLS, our study aims to evaluate the association between BMI and perioperative outcomes following L-LLS.

Methods

This was a retrospective review of 2963 patients who underwent pure L-LLS at 59 international centers between 2004–2021. All institutions obtained their respective approvals according to their local center's requirements. This study was approved by the Singapore General Hospital Institution Review Board, and the need for patient consent was waived. The anonymized data were collected in the individual centers. These were collated and analyzed centrally at the Singapore General Hospital.

Patients who underwent multiple liver resections and patients who had a history of liver resections were excluded. Additionally, patients who underwent concomitant major operations such as bilio-enteric anastomoses, lymph node dissection, colectomies, stoma reversal, gastrectomies, splenectomies, and vascular resections were excluded. Notably, patients who underwent concomitant minor operations such as hernia repair and ablations were included. After the exclusion criteria, there were 2363 cases. Of these, 180 had missing BMI data. Finally, 2183 L-LLS were included in this study.

Definitions

Liver resections were defined according to the 2000 Brisbane classification (16). LLS were classified as resection segments 2 and 3. Diameter of the largest lesion was used in the cases of multiple tumors. Difficulty of resections were graded according to the Iwate score. Post-operative complications were classified according to the Clavien-Dindo classification and recorded for up to 30 days or during the same hospitalization (17).

Statistical analyses

Body mass index was categorized into four categories: underweight (< 18.5kg/m^2), normal BMI (18.5–24.9 kg/m^2), overweight (25.0–29.9kg/m^2), and obese (≥30.0kg/m^2). Continuous and categorical variables were compared between BMI group using Kruskal Wallis and Fisher's exact tests respectively, and omnibus P-values < 0.05 were interpreted to indicate statistically-significant differences between categories (Table 1). As it is conceivable that the dose-response relationships between BMI and perioperative outcomes could be non-linear or even non-monotonic, we also analyzed associations using restricted cubic splines. This approach makes fewer a priori assumptions in regards to model specification compared to standard regression approaches which typically assume linear or log-linear relationships. The number of knots, between 3 to 7, was chosen based on minimizing the Akaike information criterion (AIC) of robust regression or modified Poisson regression models for continuous and binary endpoints respectively, adjusted for all baseline characteristics (age, sex, year of surgery, previous abdominal surgery, ASA category, pathology, tumor size, multifocal tumors, and Iwate score) and centered at their means or point estimates for proportions. We analyzed the impact of geographical region (East vs West) using simple subgroup analysis, as we found that introduction of a covariate interaction term between BMI and region led to poor model fit and extreme effect sizes. Knot locations were placed at the recommended percentiles according to the Harrell and colleagues (18). Adjusted effect sizes (mean differences or relative risks for continuous and binary outcomes respectively) were visually rendered in Figure 1 and summarized in Table 2.

Results

The baseline characteristics of the 2183 patients are summarized in Table 1. Of the 2183 patients, a total of 985 patients (45.2%) had a BMI of ≥25kg/m2. The median age was 61 years (range, 50–70) and males accounted for 58.0% of this cohort. A total of 1716 patients (78.6%) had an ASA score of 1 or 2. Malignant neoplasms accounted for 72.2% (n=1573) of all liver resections. The median tumour size was 35mm (range, 22–66mm) with a median Iwate difficulty score of 5 (range, 4–5), while approximately 14.6% (n=319) had surgery performed for multiple tumours. The overall mean postoperative length of stay was 6 days. Operative conversions accounted for 3.4% of this series (n=74), with major morbidity of 2.9% (n=63). The overall 30- and 90-day mortality was 0.3% (n=7) and 0.6% (n=13), respectively. Both mean blood loss (178 vs. 143 vs. 168 vs. 212 ml in underweight, normal weight, overweight and obese patients, respectively; p < 0.001) and operating time (177 vs. 161 vs. 183 vs. 192 minutes in underweight, normal weight, overweight and obese patients, respectively; p < 0.001) were greater in patients with higher BMI. Patients who were obese

(BMI ≥30kg/m2) had a lower post-operative length of stay as compared to those who were not obese (5 vs 6 days; p =0.005).

Comparison between patients stratified by BMI

The modeled effect sizes from restricted cubic splines analyses between BMI and peri-operative outcomes among patients undergoing L-LLS are summarized in Table 2 and visually represented in Figure 1. A BMI of >27kg/m2 was associated with a reduction in post-operative stay (MD −0.2 days, 95% CI −0.3 to −0.1) and an increased risk of blood loss (Mean difference (MD) 21mls, 95% CI 5 – 36), open conversions (Relative risk (RR) 1.13, 95% CI 1.03 – 1.25), operative time (MD 11 minutes, 95% CI 6–16) and use of pringles maneuver (RR 1.15, 95% CI 1.06−1.26).

In addition, with every unit increase in BMI, there was an increase in the magnitude of MD and RR. At a BMI of 40, the MD in operative time was 27 minutes (95% CI 6–49) and the MD in blood loss was 86mls (95% CI 15–156) while the RR of need for pringles and post-operative complications was 1.39 (95% CI 1.02–1.90) and 1.93 (95% CI 1.21–3.09) respectively. The magnitude of change observed in open conversions (RR 1.84, 95% CI 1.01–3.36) and postoperative length of stay (MD −0.6 days, 95% CI −1.1 to −0.1) reached a peak when the BMI was 39.

Post-operative complications were more frequent when patients had a BMI of >30kg/m2 (RR 1.25, 95% CI 1.03 – 1.51) or < 18.5kg/m^2.

Subset analyses of patients stratified by Eastern and Western centers

There were 1009 procedures performed in Eastern centers and 1174 in Western centers. The distribution of patients in Eastern centers were 46 (4.6%) underweight, 632 (62.6%) normal weight, 278 (27.6%) overweight and 53 (5.3%) overweight. In Western centers, there were 38 (3.2%) underweight, 482 (41.1%) normal weight), 444 (37.8%) overweight and 210 (17.9%) overweight.

Subset analyses in Eastern centers demonstrated similar results to the overall cohort whereby a higher BMI was associated with increased blood loss, intraoperative blood transfusion rate and operation time (Supplemental Figures 1–3). Similarly, a “U” shaped association was observed between BMI and postoperative morbidity (Supplemental Figure 4). However, there was no linear correlation between postoperative length of stay and BMI (Supplemental Figure 5).

Similarly, subset analyses in Western centers demonstrated linear correlation between BMI and blood loss, blood transfusion rate, open conversion rate and operation time (Supplemental Figures 6–9) and a “U” shaped association with postoperative morbidity (Supplemental Figure 10). Postoperative length of stay did not correlate with an increasing BMI (Supplemental Figure 11).

Discussion

In this study, we demonstrated that increasing BMI was associated with increasing difficulty of L-LLS (Figure 1) as evidenced by the increasing operation time, blood loss, blood transfusion, open conversion rate and frequency of use of the Pringle Maneuver. The magnitude of these adverse outcomes increased with every unit increase in an individual's BMI. However notably, postoperative morbidity demonstrated a "U" shaped association with BMI whereby underweight and obese patients experienced the highest morbidity rate.

The L-LLS is one of the most commonly performed minimally invasive liver resection and has been advocated as the procedure of choice for new surgeons embarking on LLR (19) owing to its anatomically favorable location, ease of glissonian and outflow control and predictable parenchymal transection line, allowing for a safe and efficient dissection with good outcomes even in patients with cirrhosis (20–22). Presently, the Iwate difficulty scoring systems assessing the technical difficulty of L-LLS will score with a difficulty ranging from low (11) to intermediate (9). However notably, BMI was not included in the Iwate system. Presently, there is limited data on the influence of obesity on MILR and its effect on operative outcomes remains contentious. Moreover, previous studies included all extends of liver resections but not specific types although intuitively, the impact of BMI would differ between different types of liver resections (14).

One possibility for the observed results in our study may revolve around the presence of non-alcoholic fatty liver disease (NAFLD), a disease spectrum ranging from isolated fatty infiltration of the liver to non-alcoholic steatohepatitis (NASH) and progressive liver cirrhosis (23). NAFLD has an estimated prevalence of between 15–30% in the general population (24, 25), with figures increasing in the presence of obesity. In fact, studies in obese patients reveal that NAFLD complicates over 80% of patients undergoing bariatric surgery, with over 25% of patients demonstrating biopsy proven NASH (26).

The parenchymal changes of NAFLD influence difficulty in L-LLS in various ways, depending on where it rests on the disease spectrum. On one end, livers with NAFLD have excessive intra-hepatic triglyceride accumulation, resulting in large, soft friable livers prone to intra-operative fracture and bleeding. The resultant hepatomegaly also renders liver mobilization and liver manipulation more challenging, particularly in instances when maneuvres are required to control hemorrhage. On the other hand, livers with NASH related cirrhosis present with difficulties inherent to any patient with cirrhosis. The resultant fibrosis often renders parenchymal breakage and dissection of small bilovascular elements challenging. The presence of portal hypertension and thrombocytopenia among cirrhotic patients also further elevates the risk of bleeding during parenchymal transection. In addition, the presence of visceral adiposity may compound difficulty by affording a smaller operative space and poor visual exposure in addition to an already enlarged liver, the amalgamation of these reasons possibly accounting for the increased operative time, blood loss, morbidity, and operative conversions (27, 28).

Beyond the adverse peri-operative outcomes associated with BMI, we also found that post-operative length of stay appeared to decrease with an increasing BMI, suggesting that overweight and obese patients had a shorter postoperative length of stay following L-LLS compared to their normal or underweight counterparts. This may be in part due to the protective effects of better nutrition and adequate fat stores among patients with a higher BMI (29, 30). However, a more likely explanation would be due to the confounding effect of policy differences between healthcare systems around the world. In Western centers, there is a consensus for greater independent care, functional recovery, and early discharge in order to ease the overall medical costs. On the contrary, Asian centers see patients rely heavily on external assistance for self-care, leading to prolonged hospital stay till an appropriate caregiver or step-down facility is available, particularly in an aging population. As shown in this study, whereby patients with higher BMI were more likely to be from Western centers while those with lower BMI were more likely from Asian centers, it is possible that the observed lower post-operative stay may be due to this confounding factor. This hypothesis is further supported by our findings on subset analyses whereby there was no correlation between BMI and length of stay in either Western or Eastern centers.

Another important observation which should be highlighted was with regards to major morbidity and overall morbidity which showed a “U” shaped association with BMI (Figure 1). Patients undergoing L-LLS experienced the highest rates of morbidity and major complications at the extreme ends of BMI. Patients at the lower extreme of BMI may have cachexia which is a well-known predisposing factor to increased postoperative morbidity. Similarly on the other extreme of BMI, obese patients are predisposed to postoperative complications resulting in the “U” shaped curve.

Prior studies evaluating the role of laparoscopic liver resections in overweight or obese patients have established its safety and benefit through reductions in overall morbidity as opposed to its open counterpart (27, 31), reflecting the recognized benefits of a minimally invasive approach. Among patients solely undergoing laparoscopic liver resections, the impact of BMI has remained contentious. A large retrospective series by Yu et al (29) demonstrated an increase in operative conversions among patients with higher BMI but not mortality or blood loss. It is noteworthy that a large proportion Yu’s series included patients undergoing hepatectomy for benign pathologies. Moreover, obese patients (defined as a BMI ≥28kg/m2) only accounted for approximately 5% of the overall study population. In contrast, the predominant indication for L-LLS in this series was malignancy. Consequently, variables including tumour size and the anatomic proximity to major inflow or hepatic vein outflow theoretically predisposes to an increased risk of bleeding. Additionally, the proportion of obese patients (defined as BMI ≥30kg/m) accounted for approximately 12% of this series, possibly contributing to a higher proportion of NALFD-related parenchymal changes, which could potentially explain why an increase in blood loss was noted in our series.

To our knowledge, this study is the largest series evaluating the role of BMI on outcomes following L-LLS. The addition of rigorous statistical analysis using restricted cubic splines increases the robustness of these findings by recognizing non-linear, non-monotonic relationships between exposure and outcome, thereby uncovering more precise correlations. However, there are several limitations which should be acknowledged. Firstly, the retrospective nature of this study renders it prone to confounding and bias. Secondly, as an international multi-center study, there is invariably heterogeneity across centers with respect to patient selection, surgeon experience, and perioperative management. Furthermore, as this study included patients from both Eastern and Western population, this may have an effect on outcomes due to the different implications of BMI between both populations. Hence some the BMI cutoffs for obesity differs between Eastern and Western countries. It has been shown that Asians tend to have a higher body fat ratio and higher percentages of visceral as opposed to peripheral adiposity when compared to their western counterparts for the same age, gender, and BMI (27, 32).

Conclusion

L-LLS in patients with an increasing BMI is associated with higher open conversion rates, operative morbidity, greater intraoperative blood loss, use of pringles and longer operation time. Postoperative morbidity however demonstrated a "U"-shaped association with increasing BMI. The significance of BMI as a predictor of difficulty should therefore be given consideration as an important variable in future difficulty scores.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Declarations

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

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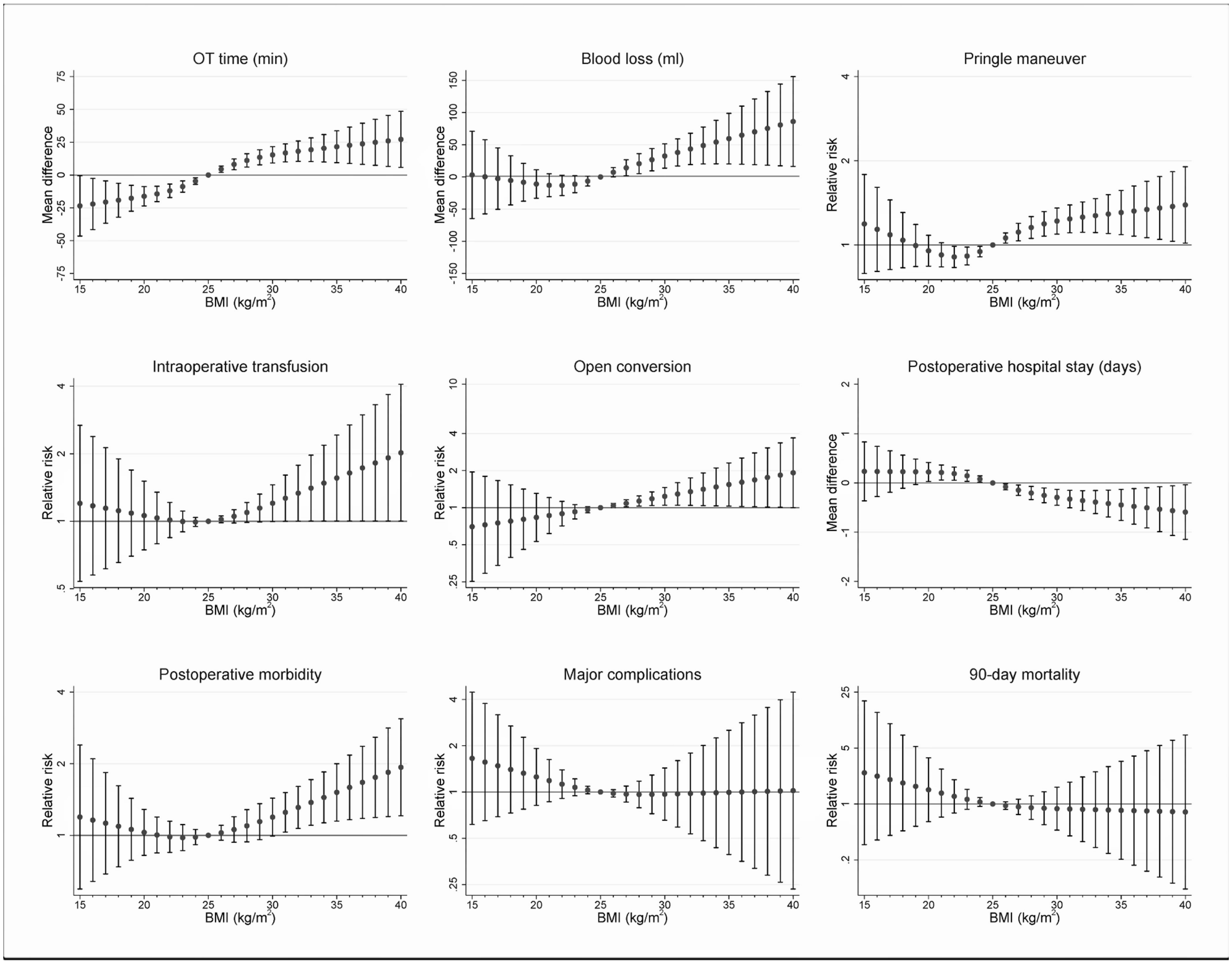

Figure 1.
Graphical representation of the modelled effect sizes from restricted cubic splines (RCS) analyses, depicting adjusted association between BMI and perioperative outcomes.

Table 1.

Comparison between baseline characteristics and perioperative outcomes of L-LLS stratified by BMI

	All N = 2183	Underweight (BMI < 18.5 kg/m^2) N = 84	Normal BMI (BMI 18.5–24.9 kg/m^2) N = 1114	Overweight (BMI 25.0–29.9kg/m^2) N = 722	Obese (BMI ≥ 30.0 kg/m^2) N = 263	P-value
Median age (IQR), yrs	61 (50–70)	59 (42–72)	59 (49–69)	63 (53–71)	61 (53–71)	<0.001
Male sex, n (%)	1266 (58.0%)	31 (36.9%)	643 (57.7%)	459 (63.6%)	133 (50.6%)	<0.001
Year of surgery, n (%)						0.262
2004–2009	182 (8.3%)	7 (8.3%)	88 (7.9%)	62 (8.6%)	25 (9.5%)	
2010–2015	666 (30.5%)	35 (41.7%)	328 (29.4%)	217 (30.1%)	86 (32.7%)	
2016–2021	1335 (61.2%)	42 (50.0%)	698 (62.7%)	443 (61.3%)	152 (57.8%)	
Previous abdominal surgery, n/total (%)	610/2104 (29.0%)	16/82 (19.5%)	277/1078 (25.7%)	216/691 (31.3%)	101/253 (39.9%)	<0.001
ASA score, n/total (%)						<0.001
1/2	1716/2182 (78.6%)	64/84 (76.2%)	930/1113 (83.6%)	539/722 (74.6%)	183/263 (69.6%)	
3/4	466/2182 (21.4%)	20/84 (23.8%)	183/1113 (16.4%)	183/722 (25.4%)	80/263 (30.4%)	
Pathology						0.007
HCC/ICC/cholangiohepatoma	1076/2179 (49.4%)	39/84 (46.4%)	586/1113 (52.7)	342/719 (47.6)	109/263 (41.4)	
CRLM	378/2179 (17.3%)	8/84 (9.5%)	172/1113 (15.5)	146/719 (20.3)	52/263 (19.8)	
Other metastases	106/2179 (4.9%)	6/84 (7.2%)	47/1113 (4.2)	38/719 (5.2)	15/263 (5.7)	
Other primary malignancy	13/2179 (0.6%)	0/84 (0.0%)	8/1113 (0.7)	5/719 (0.7)	0/263 (0.0)	
Benign	606/2179 (27.8%)	31/84 (36.9%)	300/1113 (26.9)	188/719 (26.2)	87/263 (33.1)	
Median tumor size, mm (IQR)	35 (22–60)	40 (23–60)	32 (20–57)	38 (24–60)	40 (25–70)	0.002
Multiple tumors, n (%)	319 (14.6%)	6 (7.1%)	149 (13.4%)	111 (15.4%)	53 (20.2%)	0.008
Median Iwate difficulty score, (IQR)	5 (4–5)	5 (4–5)	5 (4–5)	5 (4–5)	5 (4–5)	0.579
Iwate difficulty, n (%)	136 (6.2%)	2 (2.4%)	71 (6.4%)	50 (6.9%)	13 (4.9%)	0.608
Low	2025 (92.8%)	81 (96.4%)	1033 (92.7%)	663 (91.8%)	248 (94.3%)	
Intermediate High	22 (1.0%)	1 (1.2%)	10 (0.9%)	9 (1.3%)	2 (0.8%)	
Expert	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
Open conversion, n (%)	74 (3.4%)	5 (6.0%)	26 (2.3%)	31 (4.3%)	12 (4.6%)	0.025
Mean operating time (SD), min	173 (89)	177 (181)	161 (79)	183 (84)	192 (94)	<0.001
Mean blood loss (SD), ml	161 (251)	178 (408)	143 (223)	168 (222)	212 (350)	<0.001
Intraoperative blood transfusion, n (%)	75 (3.4%)	3 (3.6%)	37 (3.3%)	21 (2.9%)	14 (5.3%)	0.325
Pringle maneuver applied, n/total (%)	417/2102 (19.8%)	16/79 (20.3%)	197/1074 (18.3%)	139/697 (19.9%)	65/252 (25.8%)	0.072
Mean postoperative stay (SD), days	6 (5)	6 (4)	6 (5)	6 (5)	5 (4)	0.005
Postoperative morbidity, n (%)	273 (12.5%)	12 (14.3%)	127 (11.4%)	90 (12.5%)	44 (16.7%)	0.124
Major morbidity (Clavien-Dindo grade ≥ 3)	63 (2.9%)	1 (1.2%)	38 (3.4%)	18 (2.5%)	6 (2.3%)	0.556
30-day mortality, n (%)	7 (0.3%)	0 (0.0%)	4 (0.4%)	2 (0.3%)	1 (0.4%)	1.000

	All N = 2183	Underweight (BMI < 18.5 kg/m^2) N = 84	Normal BMI (BMI 18.5–24.9 kg/m^2) N = 1114	Overweight (BMI 25.0–29.9kg/m^2) N = 722	Obese (BMI ≥ 30.0 kg/m^2) N = 263	P-value
90-day mortality, n (%)	13 (0.6%)	1 (1.2%)	8 (0.7%)	3 (0.4)	1 (0.4%)	0.581

Table 2.

Modelled effect sizes from restricted cubic splines (RCS) analyses, depicting adjusted association between BMI and perioperative outcomes of laparoscopic liver resection. Reference BMI is set as 25kg/m^2 and treatment effects were adjusted using covariance adjustment for baseline covariates

BMI (kg/m^2)	Operation time (mins) MD (95% CI)	Estimated blood loss (ml) MD (95% CI)	Pringle maneuver RR (95% CI)	Blood transfusion RR (95% CI)	Open conversion RR (95% CI)	Post-op complications RR (95% CI)	Major complications RR (95% CI)	Post-op length of stay MD (95% CI)	90-day mortality RR (95% CI)
15	−24 (−46 to −1)	3 (−65 to 71)	1.19 (0.79 to 1.79)	1.2 (0.54 to 2.68)	0.7 (0.25 to 1.95)	1.19 (0.59 to 2.4)	1.66 (0.61 to 4.46)	0.2 (−0.4 to 0.8)	2.46 (0.31 to 19.42)
16	−22 (−42 to −3)	0 (−57 to 58)	1.14 (0.8 to 1.61)	1.17 (0.58 to 2.39)	0.73 (0.29 to 1.8)	1.16 (0.64 to 2.1)	1.57 (0.65 to 3.77)	0.2 (−0.3 to 0.7)	2.23 (0.36 to 13.99)
17	−21 (−37 to −4)	−3 (−50 to 45)	1.09 (0.82 to 1.45)	1.14 (0.61 to 2.13)	0.75 (0.34 to 1.66)	1.12 (0.69 to 1.84)	1.48 (0.69 to 3.18)	0.2 (−0.2 to 0.7)	2.02 (0.41 to 10.08)
18	−19 (−32 to −6)	−5 (−44 to 33)	1.04 (0.83 to 1.31)	1.12 (0.65 to 1.9)	0.78 (0.39 to 1.53)	1.09 (0.74 to 1.62)	1.4 (0.73 to 2.69)	0.2 (−0.1 to 0.6)	1.83 (0.46 to 7.26)
19	−18 (−28 to −8)	−8 (−38 to 21)	1 (0.84 to 1.18)	1.09 (0.7 to 1.69)	0.81 (0.46 to 1.42)	1.06 (0.79 to 1.43)	1.32 (0.77 to 2.27)	0.2 (0 to 0.5)	1.66 (0.53 to 5.24)
20	−16 (−24 to −9)	−11 (−33 to 11)	0.95 (0.84 to 1.08)	1.06 (0.74 to 1.51)	0.83 (0.53 to 1.31)	1.03 (0.82 to 1.29)	1.25 (0.82 to 1.92)	0.2 (0 to 0.4)	1.51 (0.6 to 3.78)
21	−14 (−20 to −9)	−13 (−31 to 5)	0.92 (0.83 to 1.02)	1.03 (0.79 to 1.35)	0.86 (0.62 to 1.21)	1 (0.84 to 1.19)	1.19 (0.86 to 1.63)	0.2 (0.1 to 0.4)	1.37 (0.69 to 2.74)
22	−12 (−17 to −7)	−13 (−29 to 3)	0.91 (0.83 to 0.99)	1.01 (0.84 to 1.21)	0.89 (0.71 to 1.13)	0.99 (0.85 to 1.15)	1.12 (0.91 to 1.39)	0.2 (0.1 to 0.3)	1.25 (0.77 to 2.01)
23	−9 (−13 to −5)	−11 (−24 to 2)	0.91 (0.85 to 0.98)	1 (0.9 to 1.11)	0.93 (0.81 to 1.06)	0.98 (0.86 to 1.11)	1.07 (0.95 to 1.22)	0.2 (0 to 0.3)	1.14 (0.86 to 1.53)
24	−5 (−7 to −2)	−7 (−14 to 1)	0.95 (0.91 to 0.99)	0.99 (0.95 to 1.04)	0.96 (0.91 to 1.02)	0.98 (0.91 to 1.06)	1.03 (0.97 to 1.09)	0.1 (0 to 0.1)	1.06 (0.93 to 1.21)
25	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
26	4 (2 to 7)	7 (0 to 15)	1.06 (1.02 to 1.1)	1.02 (0.98 to 1.06)	1.04 (1 to 1.08)	1.03 (0.95 to 1.1)	0.98 (0.93 to 1.04)	−0.1 (−0.1 to 0)	0.96 (0.86 to 1.07)
27	8 (4 to 12)	14 (2 to 27)	1.11 (1.03 to 1.19)	1.05 (0.98 to 1.13)	1.09 (1.01 to 1.16)	1.06 (0.93 to 1.2)	0.97 (0.86 to 1.09)	−0.2 (−0.3 to 0)	0.92 (0.74 to 1.15)
28	11 (6 to 16)	21 (5 to 36)	1.15 (1.06 to 1.26)	1.09 (0.99 to 1.21)	1.13 (1.03 to 1.25)	1.1 (0.94 to 1.28)	0.96 (0.79 to 1.18)	−0.2 (−0.3 to −0.1)	0.9 (0.64 to 1.27)
29	13 (8 to 19)	27 (9 to 44)	1.19 (1.08 to 1.32)	1.15 (0.99 to 1.32)	1.18 (1.04 to 1.34)	1.14 (0.96 to 1.36)	0.96 (0.72 to 1.29)	−0.3 (−0.4 to −0.1)	0.89 (0.55 to 1.42)
30	15 (9 to 22)	32 (14 to 51)	1.22 (1.09 to 1.36)	1.2 (1 to 1.45)	1.24 (1.05 to 1.46)	1.19 (0.99 to 1.43)	0.97 (0.65 to 1.43)	−0.3 (−0.5 to −0.1)	0.88 (0.47 to 1.63)

BMI (kg/m ^{2})	Operation time (mins) MD (95% CI)	Estimated blood loss (ml) MD (95% CI)	Pringle maneuver RR (95% CI)	Blood transfusion RR (95% CI)	Open conversion RR (95% CI)	Post-op complications RR (95% CI)	Major complications RR (95% CI)	Post-op length of stay MD (95% CI)	90-day mortality RR (95% CI)
31	17 (10 to 24)	38 (17 to 59)	1.24 (1.11 to 1.39)	1.27 (1 to 1.61)	1.29 (1.05 to 1.59)	1.25 (1.03 to 1.51)	0.97 (0.59 to 1.6)	−0.3 (−0.5 to −0.2)	0.87 (0.4 to 1.88)
32	18 (10 to 26)	43 (19 to 68)	1.26 (1.11 to 1.42)	1.33 (1 to 1.78)	1.35 (1.04 to 1.75)	1.31 (1.07 to 1.61)	0.98 (0.53 to 1.79)	−0.4 (−0.6 to −0.2)	0.86 (0.34 to 2.18)
33	19 (10 to 28)	49 (20 to 77)	1.27 (1.11 to 1.47)	1.41 (1 to 1.97)	1.41 (1.04 to 1.91)	1.38 (1.1 to 1.72)	0.98 (0.48 to 2.01)	−0.4 (−0.6 to −0.2)	0.85 (0.29 to 2.53)
34	20 (10 to 31)	54 (20 to 88)	1.29 (1.1 to 1.51)	1.48 (1 to 2.19)	1.47 (1.03 to 2.1)	1.44 (1.13 to 1.85)	0.99 (0.43 to 2.25)	−0.4 (−0.7 to −0.2)	0.84 (0.24 to 2.94)
35	22 (9 to 34)	59 (20 to 99)	1.31 (1.09 to 1.57)	1.56 (1 to 2.43)	1.54 (1.03 to 2.31)	1.52 (1.15 to 2)	0.99 (0.39 to 2.52)	−0.5 (−0.8 to −0.1)	0.83 (0.2 to 3.42)
36	23 (9 to 37)	65 (20 to 110)	1.32 (1.08 to 1.63)	1.64 (1 to 2.69)	1.61 (1.02 to 2.53)	1.59 (1.16 to 2.17)	1 (0.35 to 2.82)	−0.5 (−0.8 to −0.1)	0.83 (0.17 to 3.98)
37	24 (8 to 39)	70 (19 to 121)	1.34 (1.06 to 1.69)	1.73 (1 to 2.98)	1.68 (1.02 to 2.78)	1.67 (1.18 to 2.37)	1 (0.32 to 3.16)	−0.5 (−0.9 to −0.1)	0.82 (0.14 to 4.63)
38	25 (7 to 42)	75 (18 to 133)	1.36 (1.05 to 1.76)	1.82 (1 to 3.31)	1.76 (1.01 to 3.06)	1.75 (1.19 to 2.59)	1.01 (0.29 to 3.55)	−0.5 (−1 to −0.1)	0.81 (0.12 to 5.39)
39	26 (7 to 45)	81 (17 to 144)	1.37 (1.03 to 1.83)	1.92 (1 to 3.67)	1.84 (1.01 to 3.36)	1.84 (1.2 to 2.83)	1.02 (0.26 to 3.98)	−0.6 (−1.1 to −0.1)	0.8 (0.1 to 6.27)
40	27 (6 to 49)	86 (16 to 156)	1.39 (1.02 to 1.9)	2.02 (1 to 4.08)	1.92 (1 to 3.69)	1.93 (1.21 to 3.09)	1.02 (0.23 to 4.46)	−0.6 (−1.2 to 0)	0.8 (0.09 to 7.3)