Original Article

Propensity score-matched analysis examining the role of obesity on outcomes in retroperitoneal laparoscopic adrenalectomy: a cohort study

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Background: There is inconsistent evidence regarding obesity's effect on surgical outcomes following retroperitoneal laparoscopic adrenalectomy (RLA). This study aimed to investigate the influence of obesity on surgical outcomes in patients undergoing RLA, with an emphasis on operative time, drainage tube removal time, postoperative hospital stays and perioperative complications.

Methods: In this retrospective, single-center, observational study, all consecutive cases of unilateral RLA for adrenal disease from January 2012 to December 2021 were incorporated. The patients were divided into two groups based on their body mass index (BMI) of 28 kg/m^2. To mitigate selection bias, propensity score matching (PSM) was conducted, using logistic regression to calculate propensity scores for balancing baseline characteristics. A multivariate logistic regression analysis was performed to assess how obesity affects operative time and intraoperative blood loss as well. The linear correlation between BMI and surgical outcomes, including prolonged operative time and increased intraoperative blood loss, was also examined using restricted cubic spline (RCS) analysis.

Results: A total of 569 patients who underwent RLA were included. After PSM, 122 patients were apportioned to each group. Statistically significant differences were observed between the obese and non-obese group in operative time (97.5 *vs.* 115 min, P<0.001). There were no statistically significant differences between the two groups regarding hospital stay (6.7 *vs.* 6.8 days, P=0.58), drainage tube removal time (3.0 *vs.* 3.0 days, P=0.19), nor postoperative complications (9.0% *vs.* 12.3%, P=0.41). Furthermore, univariate logistic regression analysis revealed that, obese patients undergoing RLA were linked to prolonged operative time and increased intraoperative blood loss. After adjusting for potential confounders, the obese group showed a 67% increased risk of prolonged operative time and a 69% increased intraoperative blood loss. The RCS analysis revealed that BMI had a linear relationship with operative time (P for nonlinearity =0.47) and blood loss during surgery (P for linearity =0.89).

Conclusions: In patients undergoing RLA, obesity exerts a significant influence on surgical outcomes, particularly with regard to operative time and intraoperative blood loss, as shown in multivariable logistic regression analysis and PSM to balance baseline characteristics.

Keywords: Laparoscopic adrenalectomy (LA); obesity; body mass index (BMI); perioperative outcomes

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Introduction

In the treatment of most benign and malignant adrenal lesions, laparoscopic adrenalectomy (LA) is considered the gold standard procedure (1). It is most commonly performed through a transperitoneal or retroperitoneal approach for the removal of adrenal glands, although several other approaches have been reported for LA (2). The advantages of retroperitoneal laparoscopic adrenalectomy (RLA) over transperitoneal laparoscopic adrenalectomy (TLA) include avoiding abdominal complications and intestinal interference, which is conducive to intestinal recovery (3).

Obesity is considered a risk factor for increased surgical complexity and perioperative complications in almost all surgical procedures (4,5). In open surgeries, the visualization of the surgical field in obese patients is a major concern due to the extensive presence of adipose tissue, which potentially leads to prolonged operative times and larger surgical incisions. Consequently, obese patients frequently require larger abdominal incisions, which forces them to endure heightened postoperative pain as well as prolonged recovery periods. Moreover, obesity causes increased risk of wound infections as adipose tissue is hypoperfused and poorly oxygenated (6-8), thus, obese patients face an increased risk of developing conditions such as lung collapse and other pulmonary complications.

However, whether obesity adversely affects surgical outcomes remains controversial in the field of laparoscopic surgery. Several studies have reported the effect of obesity on surgical outcomes of LA, in which conclusions are inconsistent (9,10). Therefore, it remains unclear whether obesity adversely affects surgical outcomes of RLA. Body mass index (BMI) is a common indicator used to measure obesity. This study aims to investigate if obesity, as per the Chinese-specific BMI definition, has a significant impact on surgical outcomes in patients undergoing RLA, particularly with regard to operative time and intraoperative blood loss. This study's findings will be a supplement to the existing knowledge regarding the implications of obesity in RLA and will provide guidance to clinical decision-making, ultimately enhancing surgical outcomes in this context. We present this article in accordance with the STROBE reporting checklist (available at https://gs.amegroups.com/article/view/10.21037/gs-24-37/rc).

Highlight box

Key findings

- After balance the distribution of baseline characteristics, obesity was independently associated with worse surgical outcome, including prolonged operative time and increased intraoperative blood loss.

What is known and what is new?

- Obesity is considered a risk factor for increased surgical complexity and perioperative complications in almost all surgical procedures, which causes larger abdominal incisions, prolonged recovery periods and increased risk of wound infections. However, there is inconsistent evidence regarding obesity's effect on surgical outcomes in the field of laparoscopic surgery.
- By balancing baseline characteristics with propensity score matching, obesity was identified as a risk factor for prolonged operative times. It also contributes to increased intraoperative blood loss according to the multivariable regression.

What is the implication, and what should change now?

- Particular attention to operative procedure and postoperative care should be paid to obese patients undergoing retroperitoneal laparoscopic adrenalectomy. Operation must be performed carefully and careful wound care should be emphasized. Further improvement of surgical procedure and postoperative protocol are warranted. Moreover, there is a need for further study into how obesity affects surgical outcomes.

Methods

Study design and population

A retrospective analysis was conducted by reviewing the medical records of 569 consecutive patients who underwent RLA for adrenal diseases from January 2012 to December 2021 in the Department of Urology, Beijing Anzhen Hospital, Capital Medical University. The inclusion criteria were: (I) patients diagnosed with adrenal lesions, including adrenal adenoma and hyperplasia; (II) patients undergoing RLA; Exclusion criteria were: (I) patients undergoing TLA; (II) patients undergoing robot-assisted RLA; (III) patients with previous ipsilateral retroperitoneal surgery; (IV) conversion to open surgery intraoperatively; (V) other pathological types of adrenal lesions, including adrenal malignant tumors, cysts, and myelolipomas. In accordance with the Chinese BMI criteria, BMI was categorized as underweight (BMI <18.5 kg/m^2), normal (18.5 kg/m^2≤ BMI <24 kg/m^2), overweight (24 kg/m^2≤ BMI <28 kg/m^2) and obese (BMI ≥28 kg/m^2). Here, a BMI ≥28 kg/m^2 was used as the cut-off for determining obesity.

Based on the following hospital discharge criteria in our center, the attending surgeons determined the postoperative

discharge: (I) the patient's overall condition should display satisfactory improvements, including a successful return to a regular diet and normal bowel function; (II) removal of the retroperitoneal drainage tube; (III) satisfactory postoperative physical performance was demonstrated by patients' ability to walk safely and independently; (IV) sustained normal body temperature and pertinent normal or near-normal laboratory test results with no exhibition of any alarming signs; (V) neither infection nor excessive inflammation or discharge is present at the incision sites. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study protocol was approved by the ethics committee of Beijing Anzhen Hospital (No. 2024056X). Individual consent for this retrospective analysis was waived.

Data collection

The following dataset was collected: patients' sex, patients' age, operative time (measured from trocar insertion to abdominal closure), estimated intraoperative blood loss, BMI, American Society of Anesthesiologists (ASA) score, surgeon's experience (initial 30 cases), tumor lateralization (left or right), resection procedure (partial or total adrenalectomy), lesion diameter (expressed in centimeters, measured along the major axis), perioperative complications (graded according to Clavien-Dindo grades II–V) and preoperative comorbidities (hypertension, diabetes, cardiovascular disease, and respiratory disease).

We applied RLA with a lateral retroperitoneal approach for the excision of adrenal lesions, involving partial excision and total excision. The patient was placed in the full lateral kidney position under general intubated anesthesia. The skin incision was extended through the abdominal muscles to reach the transversalis fascia. Three trocar ports were established between the anterior axillary line and posterior axillary line. The pararenal fascia layer was longitudinally dissected along the curvature of the lateral margin of Gerota's fascia to access the anterior pararenal fossa after creating a retroperitoneal working space. Dissecting the interval between the perinephric fat and the surface of the kidney on the ventral side, the surgeons meticulously separated the tissue in a bottom-up process, locating the adrenal gland at the upper pole of the kidney. The adrenal gland was then gently elevated cranially by grasping the periadrenal fat. The periadrenal tissue between the kidney and adrenal was incised along the lower adrenal border. The central adrenal vein is dissected, with the latter being doubly clipped and transected typically from the ventral aspect of the adrenal gland. Utilization of an ultrasonically activated scalpel greatly facilitated all procedures by effectively coagulating and cutting small vessels within the adrenal gland. A drain tube is routinely placed in the retroperitoneal space to remove peritoneal fluids.

Outcome definition

Perioperative complications, as one of the surgical outcomes, were calculated from the day of the operation to the day of hospital discharge, and were further categorized according to the Clavien-Dindo classification system. Complications with a grade of 2 or greater were included in this analysis. The media operation time of these 569 RLA cases were 105 min, and the operation time above the 75th percentile (>135 min) was determined as the cut-off value, which means that operation time >135 min was considered as prolonged operative time. In addition, the amount of blood loss is typically estimated based on the volume of suction and visual estimation. The median estimated intraoperative blood loss was 20 mL, and the cut-off value for blood loss was set to above the 75th percentile (>30 mL). An estimated intraoperative blood loss higher than 30 mL was considered as increased intraoperative blood loss.

Propensity score matching (PSM) analysis

Cofounding factors were controlled by PSM, which was performed in this study with the "MatchIt" package of R software (version 4.2.1 for Mac) and conducted with the 1:1 nearest neighbor matching method with no specified caliper distance, therefore, the demographics and comorbidities are more likely to be homogenous. The covariates incorporated in the analysis to create balanced groups were as follows: sex, age, surgeon's experience, lesion laterality, pathology type of the lesions, resection procedure, preoperative comorbidities (hypertension, diabetes, cardiovascular diseases and respiratory disease), lesion diameter and ASA score.

Statistical analysis

Normally distributed continuous variables were expressed as mean ± standard deviation, and Student's *t*-test was conducted for difference comparison between obesity and non-obesity group. Data with non-normal distributions

were provided as median plus interquartile range (IQR), and the Wilcoxon rank sum test was applied to compare them. For comparisons between groups among the categorical variables, Chi-squared test or Fisher's exact test was used as appropriate. To explore the nonlinear relationship between BMI and the risk of prolonged operative time and increased intraoperative blood loss, a three-knot restricted cubic spline (RCS) model was employed, with default knots positioned at the 10th, 50th, and 90th percentiles through the range of observed data. Additionally, univariate and multivariate logistic regression analyses were performed to evaluate the influence of BMI on the prolonged operative time and increased intraoperative blood loss. All statistical analyses were performed using R software (version 4.2.1 for Mac). A P value <0.05 was considered statistically significant.

Results

PSM

In this study, a total of 569 patients were included, with 122 patients classified as obese group (BMI ≥28 kg/m^2) and 447 patients classified as non-obese group (BMI <28 kg/m^2), whose original baseline characteristics are demonstrated in *Table 1*. To ensure comparability in baseline characteristics and rigorously assess the discrepancy between the two groups, PSM was employed. After PSM, 122 well-balanced pairs of patients were extracted. The clinical characteristics of these 244 patients are displayed in *Table 2*. There were no significant differences in age, sex, surgeon's experience, lesion laterality, ASA score, resection procedure, lesion diameter, pathology type of the lesions and preoperative comorbidities between the two groups.

Impact of obesity on RLA outcomes

In the matched cohort, the influence of obesity on the RLA outcomes is presented in *Table 3*. The median operative time was significantly longer in the obese group as compared with non-obese group (115 *vs.* 97.5 min, P<0.001). As opposed to obesity's impact on surgical duration, there was no statistically significant difference in drainage tube removal time (3.0 *vs.* 3.0 days, P=0.19) and postoperative hospital stay (6.7 *vs.* 6.8 days, P=0.58) between the obese and non-obese groups. Violin plots and a box plot was used to visualize the above results (*Figure 1*). No statistically significant disparity was noted in the rates of postoperative complications between the obese and non-obese groups (9.0% *vs.* 12.3%, P=0.41) after the baseline characteristics were matched with PSM.

Univariate and multivariable logistic regression analyses

To further investigate the impact of obesity on prolonged operative time and increased intraoperative blood loss, univariate and multivariate logistic regression analyses were conducted using the 75th percentile as cutoff for operative time and intraoperative blood loss. As a result, the incidence of prolonged operative time [odds ratio (OR) =1.67; 95% confidence interval (CI): 1.04–2.66; P=0.03] as well as increased intraoperative blood loss (OR =1.91; 95% CI: 1.24–2.95; P=0.003) was presented to be significantly higher among obese patients. Subsequently, the multivariable logistic regression analysis, adjusted for sex, lesion size, surgical approach and surgical experience, confirmed the independent influence of obesity on operative time extension (OR =1.61; 95% CI: 1.01–2.56; P=0.045) and increased intraoperative blood loss (OR =1.69; 95% CI: 1.07–2.65; P=0.02).

RCS analysis

According to the RCS, there was a linear association between BMI and the length of the surgery (*Figure 2A*, P for nonlinearity =0.47), highlighting that the operative time lengthened proportionally and consistently as BMI increased. Similarly, a significant linear correlation was observed between BMI and increased intraoperative blood loss (*Figure 2B*, P for nonlinearity =0.89). These results evidently underscore that as BMI increases, both the prolonged operative time and the amount of blood lost during surgery increases proportionally. This linear relationship reinforces the consistent and robust nature of the connection between BMI and these specific surgical outcomes. Our analysis has provided further evidence of a direct and linear relationship between BMI and the surgical difficulty of RLA, as indicated by prolonged operative time and increased intraoperative blood loss.

Discussion

As surgical techniques become more mature, the importance of preoperatively assessing surgical difficulty and risk is increasing. The focus of surgeons has shifted to developing a systematical approach that could evaluate

Table 1 Baseline characteristics of recruited patients before matching

Variables	Non-obese group	Obese group	P value
Sample size, n	447	122	–
Lesion diameter (cm), median [IQR]	1.60 [1.29, 2.00]	1.70 [1.35, 2.50]	0.046
Age (years), mean (SD)	52.51 (11.46)	51.52 (11.50)	0.40
Sex, n (%)			0.07
Male	222 (49.7)	72 (59.0)	
Female	225 (50.3)	50 (41.0)	
Surgeons' experience, n (%)			0.22
≤30 cases	139 (31.1)	31 (25.4)	
>30 cases	308 (68.9)	91 (74.6)	
Lesion laterality, n (%)			0.13
Left	255 (57.0)	79 (64.8)	
Right	192 (43.0)	43 (35.2)	
Pathology, n (%)			0.10
Adenoma	347 (77.6)	86 (70.5)	
Hyperplasia	100 (22.4)	36 (29.5)	
Resection procedure, n (%)			0.18
Partial	338 (75.6)	85 (69.7)	
Total	109 (24.4)	37 (30.3)	
Hypertension, n (%)			0.53
No	33 (7.4)	7 (5.7)	
Yes	414 (92.6)	115 (94.3)	
Diabetes, n (%)			0.28
No	340 (76.1)	87 (71.3)	
Yes	107 (23.9)	35 (28.7)	
Cardiovascular disease, n (%)			
No	356 (79.6)	97 (79.5)	0.97
Yes	91 (20.4)	25 (20.5)	
Respiratory disease, n (%)			0.03
No	426 (95.3)	110 (90.2)	
Yes	21 (4.7)	12 (9.8)	
ASA, n (%)			0.36
≤2	323 (72.3)	83 (68.0)	
>2	124 (27.7)	39 (32.0)	

IQR, interquartile range; SD, standard deviation; ASA, American Society of Anesthesiologist.

Table 2 Baseline characteristics of recruited patients after matching

Variables	Non-obese group	Obese group	P value
Sample size, n	122	122	–
Lesion diameter (cm), median [IQR]	1.90 [1.40, 2.20]	1.70 [1.35, 2.50]	0.95
Age (years), mean (SD)	49.65 (12.61)	51.52 (11.50)	0.23
Sex, n (%)			0.60
Male	76 (62.3)	72 (59.0)	
Female	46 (37.7)	50 (41.0)	
Surgeons' experience, n (%)			0.47
≤30 cases	36 (29.5)	31 (25.4)	
>30 cases	86 (70.5)	91 (74.6)	
Lesion laterality, n (%)			0.89
Left	78 (63.9)	79 (64.8)	
Right	44 (36.1)	43 (35.2)	
Pathology, n (%)			>0.99
Adenoma	86 (70.5)	86 (70.5)	
Hyperplasia	36 (29.5)	36 (29.5)	
Resection procedure, n (%)			0.39
Partial	91 (74.6)	85 (69.7)	
Total	31 (25.4)	37 (30.3)	
Hypertension, n (%)			>0.99
No	7 (5.7)	7 (5.7)	
Yes	115 (94.3)	115 (94.3)	
Diabetes, n (%)			0.47
No	92 (75.4)	87 (71.3)	
Yes	30 (24.6)	35 (28.7)	
Cardiovascular disease, n (%)			
No	91 (74.6)	97 (79.5)	0.36
Yes	31 (25.4)	25 (20.5)	
Respiratory disease, n (%)			0.83
No	111 (91.0)	110 (90.2)	
Yes	11 (9.0)	12 (9.8)	
ASA, n (%)			0.89
≤2	82 (67.2)	83 (68.0)	
>2	40 (32.8)	39 (32.0)	

IQR, interquartile range; SD, standard deviation; ASA, American Society of Anesthesiologist.

Table 3 Perioperative and postoperative clinical outcomes

Operative outcome	Non-obese	Obese	P value
Sample size, n	122	122	–
Operative time (min), median (IQR)	97.50 (80.00, 133.75)	115.00 (95.00, 148.75)	<0.001
Intraoperative blood loss (mL), median (IQR)	20.00 (10.00, 50.00)	20.00 (20.00, 50.00)	0.006
Drainage tube removal time (days), median (IQR)	3.00 (2.00, 4.00)	3.00 (2.00, 3.00)	0.19
Postoperative LOS (days), mean (SD)	6.71 (1.89)	6.84 (1.55)	0.58
Complications, n (%)			0.41
No	111 (91.0)	107 (87.7)	
Yes	11 (9.0)	15 (12.3)	

IQR, interquartile range; LOS, length of stay; SD, standard deviation.

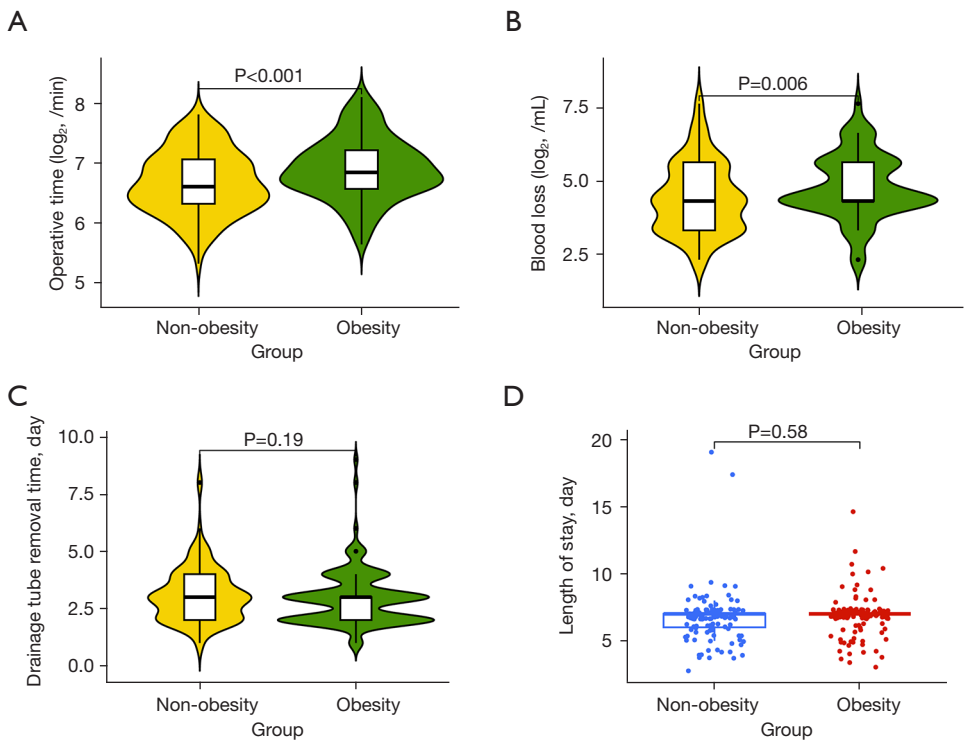

Figure 1 An analysis of surgical outcome for obese and non-obese patients after PSM based on violin and box plots. It was found that obese patients had longer operative time and more intraoperative blood loss. PSM, propensity score matching.

surgical complexity and select the appropriate approach to the surgery. Adrenal glands located within the perirenal space, enclosed by adipose tissue and encased by Gerota's fascia, present challenges in exposure of adrenal glands during adrenalectomy (11). Since adrenal glands are located deep inside the body, it can be challenging to identify and remove them safely even in individuals without obesity (12). Currently, there is still disputable regarding the impact of obesity on RLA surgical outcomes, and there is no clear consensus.

Our study clarified that obesity, a prominent concern in the surgical domain, unquestionably wielded a considerable impact on surgical outcomes. More precisely, it significantly affected the operative time and intraoperative blood loss

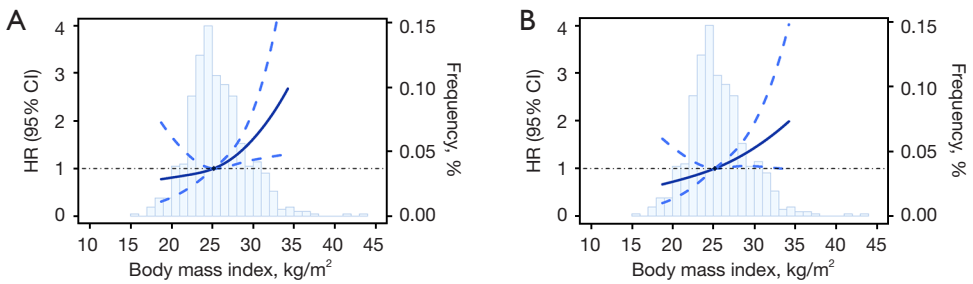

Figure 2 Multivariable-adjusted odds ratios on a continuous scale. Solid dark blue lines are multivariable-adjusted odds ratios, with dashed bold blue lines showing 95% confidence intervals derived from RCS regressions with three knots. Reference lines are indicated by the black dashed lines at a hazard ratio of 1.0, and the reference knots are set at 25 kg/m^2. Visual representation of the influence of BMI on operative time (A) and increased intraoperative blood loss (B), which demonstrates a linear association. HR, hazard ratio; CI, confidence interval; RCS, restricted cubic spline; BMI, body mass index.

during RLA, underscoring the importance of addressing this factor in clinical practice. Obese patients tend to have excess adipose tissue that obstructs blood vessel identification, making the safe isolating of adrenal glands safer more difficult. The risk of damaging other retroperitoneal organs is also increased when extensive dissection is performed in the ventral and inferior directions. These challenges are exacerbated in obese patients, with a higher risk of inadvertently dissecting in the ventral or inferior directions, potentially damaging the splenic vessels or the inferior vena cava (12-14).

In accordance with our study results, a recent study involving 353 patients undergoing RLA found that the overweight group with BMI >30 kg/m^2 had a prolonged operative time compared with the normal BMI group, but no difference was found in postoperative length of stay, estimated blood loss, or postoperative complications (10).

Generally, RLA can provide direct access to expose the adrenal tumor and avoid interference with intra-abdominal organs (15). Several studies have reported that RLA was superior, or at least comparable, to TLA in terms of operative time, estimated blood loss (EBL), and length of hospital stay (16,17). Of interest, the effect of BMI on the surgical difficulty of TLA is not consistent with the effect when using the retroperitoneal approach. The results of a prospective study by Rodríguez-Hermosa *et al.* (11) showed no increase in surgical difficulty associated with BMI, which might be due to the familiarity with abdominal anatomy and a wide working space in TLA. Furthermore, it was reported that neither intraoperative blood loss nor operative time were different between obese and non-obese patients undergoing LA via a transabdominal approach (9). It has been reported that intraoperative complications did not require open surgery, and conservative management was successful for inferior vena cava and diaphragm injuries (18). However, rapid conversion to open surgery is necessary for risky complications to prevent life-threatening events. In this way, the transabdominal approach for LA could represent a potentially useful surgical option for patients with high BMI and obesity.

It is noteworthy that while obesity was associated with these significant associations, it did not substantially affect postoperative hospital stay or postoperative complication rates, which suggest that obese patients may face challenges during surgery, but their postoperative recovery and complications are comparable to those of non-obese individuals. This finding provides a reassuring perspective on postoperative outcomes in obese individuals.

There are, however, some limitations inherent in this study that must be acknowledged. Its retrospective design introduces inherent limitations, including the possibility of selection bias and the lack of randomization. While PSM was employed to minimize selection bias and enhance comparability between the obese and non-obese groups, unmeasured confounders may still exist. Secondly, our study did not include the measurement of specific parameter of perirenal or perinephric fat. Perinephric fat has been suggested as a potential contributor to surgical complexity and outcomes in laparoscopic procedures. It is possible to gain a better understanding of the role of adipose tissue distribution by incorporating measurements of perirenal fat and its impact on RLA outcomes in future research.

Conclusions

In conclusion, our research underscores the importance of

recognizing obesity, as defined by Chinese BMI criteria, as a significant factor influencing specific LA outcomes. Patients with obesity are more likely to experience longer operating times and increased intraoperative blood loss, so surgeons and healthcare professionals should take that into account when planning and conducting these procedures. Optimal outcomes may be achieved for obese patients undergoing LA by tailoring strategies and selecting patients carefully. It would be beneficial to investigate more effective techniques and approaches for this patient population, ultimately contributing to better patient care and surgical decision-making.

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Footnote

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://gs.amegroups.com/article/view/10.21037/gs-24-37/coif). The authors have no conflicts of interest to declare.

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 study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study protocol was approved by the ethics committee of Beijing Anzhen Hospital (No. 2024056X). Individual consent for this retrospective analysis was waived.

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