Original Article

A computed tomography-based comprehensive standardized adrenal tumor scoring model for predicting the perioperative outcomes of retroperitoneal laparoscopic adrenal surgery

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Background: Many imaging scoring models have been developed for tumor surgery to provide critical guidance for the selection of surgical methods. However, little research has been aimed at developing scoring models for adrenal tumors and retroperitoneal laparoscopic adrenal surgery (RLAS), which has become the primary technique for treating adrenal tumors. The study set out to establish a computed tomography (CT)-based adrenal tumor scoring model for predicting perioperative outcomes in patients with adrenal tumors who have undergone RLAS.

Methods: The retrospective analysis included 306 patients with adrenal tumors diagnosed by preoperative unenhanced or enhanced CT from January 2014 to August 2018 in the First Affiliated Hospital of Fujian Medical University. CT images were used to quantify the tumor location and size; the relationships of the tumors with the surrounding organs and tissues, the large abdominal blood vessels, and the upper poles of the kidneys and renal hila; the adhesion of periadrenal fat (PF); and the tumor CT enhancement value. We conducted multivariate ordinal logistic regression analysis to screen variables and performed principal component analysis to construct a novel scoring model for RLAS. The perioperative outcomes of RLAS were evaluated according to postoperative length of stay, operative time (OT), intraoperative blood loss (IBL), and postoperative complications.

Results: The final scoring model included tumor size; the relationships of the tumors with the surrounding organs and tissues, the large abdominal blood vessels, and the upper poles of the kidneys and renal hila; the tumor CT enhancement value; the adhesion of the PF; and the functional status of adrenal tumors. The total

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score had positive correlations with the OT (r_s=0.431), IBL (r_s=0.446), and postoperative length (r_s=0.180) (all P values <0.001). Compared to any single metric, the total score provided better prediction of OT and IBL. The grading system for RLAS based on the scoring model also performed well in predicting the complexity and difficulty of RLAS. The coincidence rate for these factors was good (all P values <0.001).

Conclusions: The developed model is feasible and repeatable in the prediction of the perioperative outcomes, complexity, and difficulty of RLAS.

Keywords: Adrenal tumors; tumor size; CT morphology; peripheral organs; periadrenal fat (PF)

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Introduction

Laparoscopic adrenal surgery, which can be divided into transperitoneal and retroperitoneal approaches, is the standard of treatment for benign adrenal lesions. Retroperitoneal laparoscopic adrenal surgery (RLAS) has significant advantages over the transperitoneal approach, including a shorter operative time (OT), lower intraoperative blood loss (IBL), reduced recovery period, and fewer complications, which has led to it becoming the primary technique for treating adrenal tumors in China (1-3). However, not every patient may benefit from RLAS. For instance, the transperitoneal approach may be preferred in patients with large adrenal lesions due to its larger operating space. The choice of surgical approach depends on the tangible conditions of each case. In recent years, many imaging scoring models have been developed for tumor surgery (4-7) to provide critical guidance for the selection of surgical methods by systematically predicting the difficulty and complexity of tumor surgery. However, little research has been aimed at developing adrenal tumor scoring models for RLAS.

In this study, the clinical data of patients undergoing RLAS were retrospectively analyzed to develop an adrenal tumor scoring model for assessing surgical risk. CT images were used to quantify the tumor size; the relationships of the tumor with the surrounding organs, abdominal large vessels, and the upper poles of the kidneys and renal hila; the degree of periadrenal fat (PF) adhesion; the tumor computed tomography (CT) enhancement value; and the functional status of adrenal tumors. Following this, a scoring model was constructed based on these CT data. We present this article in accordance with the TRIPOD reporting checklist (available at https://qims.amegroups.com/article/view/10.21037/qims-23-764/rc).

Methods

Study population

This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Ethics Committee of the First Affiliated Hospital of Fujian Medical University (approval No. MTCA, ECFAH of FMU [2015]084-1). Written informed consent for this study was waived due its retrospective design. The clinical data of 358 patients treated at the Department of Urology of the First Affiliated Hospital of Fujian Medical University from January 2014 to August 2018 were collected consecutively and analyzed retrospectively. All patients had been diagnosed with adrenal tumors via unenhanced and enhanced CT which was conducted within 1 month before RLAS. All surgeries were performed by the same team. The perioperative outcomes of RLAS were evaluated according to postoperative length of stay, OT, IBL, and postoperative complications.

The inclusion criteria were as follows: (I) all preoperative clinical data were complete including general data (age, sex, CT data of the tumor), OT, IBL, surgical complications (e.g., surgical incision infection, lung infection), postoperative length of stay, and postoperative drainage volume; (II) all patients underwent RLAS (8-10), and the diagnosis of an adrenal tumor was pathologically confirmed after the surgery; (III) distant metastasis and widespread intra-abdominal implantation metastasis were not detected via preoperative imaging examinations (e.g., CT, magnetic resonance imaging, positron emission tomography-CT) or intraoperative exploration; and (IV) intraoperative conversion to open surgery was possible.

The exclusion criteria were as follows: (I) previous history of lumbar surgery; (II) need for combined renal

Table 1 Quantitative scores of the indicators based on CT imaging

Parameter	Score of 1	Score of 2	Score of 3
Tumor side	The left adrenal gland	The right adrenal gland	–
Tumor size	≤3 cm	>3 but ≤6 cm	>6 cm
Relationships to the upper poles of the kidneys and the renal hila	Completely above the kidney	Crossing the upper pole but not reaching the upper polar line of the kidney	Reaching the renal hila
PF	No cord-like change	Cord-like change with few and fine textures	More cord-like changes with coarse texture and adhesion
Relationships to the large abdominal blood vessels	Clear boundary	Unclear boundary and adhesion	Compression and displacement
Tumor CT enhancement	≤30 HU	>30 but ≤80 HU	>80 HU
Relationships to the surrounding organs and tissues	Clear boundary	Unclear boundary and adhesion	Compression and displacement

CT, computed tomography; PF, periadrenal fat; HU, Hounsfield unit.

surgery (e.g., renal tumor, renal cyst); (III) presence of other abdominal tumors; (IV) preoperative diagnosis of serious medical diseases (e.g., heart failure, chronic obstructive pulmonary emphysema); and (V) presence of other malignant tumor metastasis involving the adrenal glands.

Patients were divided into four groups based on the OT as follows: group I, ≤50 minutes; group II, >50 but ≤100 minutes; group III, >100 but ≤150 minutes; and group IV, >150 minutes. Similarly, patients were grouped according to IBL as follows: group I, ≤30 mL; group II, >30 but ≤100 mL; group III, >100 but ≤200 mL; and group IV, >200 mL.

Quantification of evaluation indicators

Two senior surgeons, each with more than 10 years of relevant experience, calculated the score according to the assigned numerical scores of the indicators, as detailed in *Table 1*. These indicators included tumor side; tumor size; the relationships of the tumor with the surrounding organs and tissues, the upper poles of the kidneys and renal hila, and the abdominal large vessels; the degree of PF adhesion; and tumor CT enhancement value. Quantification of these indicators is described below:

(I) Tumor side: it has been demonstrated that RLAS via the posterior approach for right adrenal tumors requires a longer OT (11). Therefore, quantification was performed according to the location of the tumor (right or left side).

(II) Tumor size: Fassnacht *et al.* concluded that adrenal tumors less than 3 cm in diameter are essentially benign (12). Cyranska-Chyrek *et al.* found that the risk of adrenal malignancy increases with increasing tumor diameter, as demonstrated by malignancy rates of less than 5% for tumors less than 6 cm in diameter and 37.7% for tumors more than 6 cm in diameter (13). In addition, malignant adrenal tumors are generally more than 6 cm in diameter (14). Consequently, 3 and 6 cm were chosen as the tumor diameter nodes for the quantitative scoring of tumor size. In this study, adrenal tumor size was measured as the longest diameter of the tumor on the largest transverse plane of CT imaging.

(III) Relationships between the tumor and the surrounding organs and tissues: the relationship between the adrenal tumor and surrounding organs and tissues, as presented in *Figure 1A-1C*, was determined according to CT data.

(IV) Relationships between the tumor and abdominal large vessels: when the adrenal tumor enlarges to approach and adhere to the inferior vena cava or abdominal aorta, the risks of large vessel injury and hemorrhage are increased. The relationships between the tumor and abdominal great vessels, as presented in *Figure 1D-1F*, were scored quantitatively according to CT data.

(V) PF on imaging: based on Mayo adhesive probability (MAP) scoring of perirenal fat which was created for kidney surgeries (15-17), a numerical score

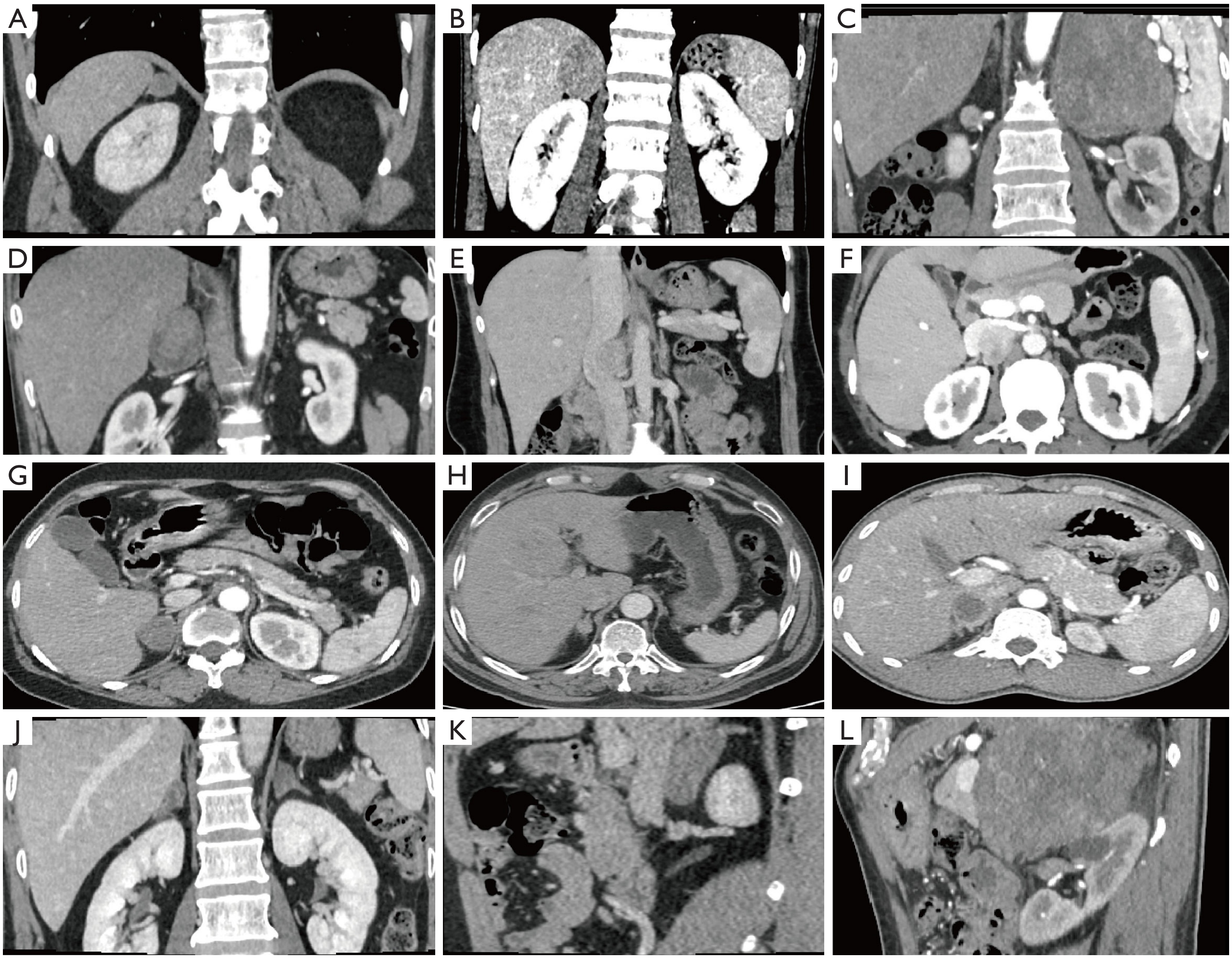

Figure 1 Schematic diagram of the quantitative indicators of adrenal tumors based on CT. (A-C) Relationship with the surrounding organs and tissues: (A) clear boundary, (B) unclear boundary and adhesion, and (C) compression and displacement. (D-F) Relationship with large abdominal blood vessels: (D) clear boundary, (E) unclear boundary and adhesion, and (F) compression and displacement. (G-I) PF: (G) no cord-like change, (H) cord-like change with a few fine textures, and (I) more cord-like changes with coarse texture and adhesion. (J-L) Relationship with the upper poles of the kidneys and renal hila: (J) completely above the kidneys, (K) crossing the upper pole without reaching the upper polar line of the kidneys, and (L) reaching the renal hila. CT, computed tomography; PF, periadrenal fat.

was assigned according to the degree of cord-like presentation of fat in the adrenal space on CT, as shown in *Figure 1G-1I*.

(VI) Relationships between the tumors and the upper poles of the kidney and renal hila: downward growth of adrenal tumors usually pushes the kidneys downward and even partially across the renal hilum vein, making surgery difficult. Hence, the numerical score was based on the relationships of the tumor with the upper renal poles and renal hila observed from the axial, sagittal, and coronal planes on CT, as presented in *Figure 1J-1L*.

The degree of CT enhancement of the adrenal tumor was scored quantitatively according to the tumor CT enhancement value.

Several studies have reported the functional status of adrenal tumors to be a risk factor in surgery (18-20). Therefore, the functional status of adrenal tumors was classified as nonfunctional (score =1) or functional (score =2) according to the endocrinological and radiological data.

To use the quantitative scoring model for evaluating the complexity and difficulty of RLAS, the following classification scheme was developed based on the total score: grade I (low complexity and difficulty), score =1; grade II (moderate complexity and difficulty), score >1 but ≤2; and grade III (high complexity and difficulty), score >2. The Kruskal-Wallis test was conducted to determine any statistical differences regarding OT, IBL, and postoperative length of stay between any two grades.

Statistical methods

Data were analyzed using SPSS 25.0 software (IBM Corp., Armonk, NY, USA), and power (1 − β) was calculated by G*power 3.3.9.7 software. The Shapiro-Wilk test was used to analyze the normality of data. All normally distributed numerical data are expressed as the mean ± standard deviation (SD), nonnormally distributed numerical data are expressed as the median with interquartile range, and qualitative data are expressed as frequency (percentage). Multivariate ordinal logistic regression was used to select the indicators related to OT and IBL. Principal component analysis was performed to confirm the specific weight of the indictors, and then the quantitative scoring model was created. Spearman correlation analysis was conducted to determine the correlation of the scoring model with OT, IBL, postoperative complications, and postoperative length of stay. The Mann-Whitney rank-sum test was performed for intergroup comparisons of postoperative complications with the scoring model, and power was calculated using G*power 3.3.9.7 software. In addition, receiver operating characteristic (ROC) curves were used to assess the prediction accuracy of the model in RLAS. Patients were divided into three groups (I, II, III) based on the scoring model. Statistical differences in OT, IBL, and postoperative length of stay among these three groups were analyzed with the Kruskal-Wallis test. Finally, kappa analysis was conducted to assess the consistency of the model for data obtained from two experienced surgeons via independent scoring. A P value <0.05 was considered statistically significant.

Results

General clinical data

In total, 306 patients were finally included in the analysis, as shown in Figure S1, and their mean age was 49.25±12.36 years. The cohort included 142 men and 164 women. Additionally, 162 tumors were located in the left adrenal gland, and 144 tumors were located in the right adrenal gland. The general clinical data of the patients (e.g., pathological type of adrenal tumors, Clavien-Dindo grade) are detailed in Table S1. No patients required intraoperative conversion to open surgery.

Establishment of a quantitative scoring model for RLAS

The six indicators displayed in *Table 1* (i.e., tumor side; tumor size; the relationships of the tumor with the surrounding organs and tissues, the upper poles of the kidneys and renal hila, and abdominal large vessels; the degree of PF adhesion; and tumor CT enhancement value) and functional status of the adrenal tumor were included and analyzed with multivariate ordinal logistic regression to select the factors of the quantitative scoring model for RLAS (*Table 2*). Six indicators (adrenal tumor size; relationships of the tumor with the upper poles of the kidneys and renal hila, the abdominal large blood vessels, and the surrounding organs and tissues; adhesion of PF; and functional status of adrenal tumors) were found to be correlated with the OT or IBL (all P values <0.05); thus, they were included into the scoring model for RLAS. The CT enhancement value likely exhibited an association with the diagnostic process of adrenal tumors; for example, the change of the value before and after CT enhancement was <20 Hounsfield units (HU) for benign tumors and >20 HU for malignant tumors (21-24). Therefore, in addition to the six indictors mentioned above, tumor CT enhancement was included in the scoring model for RLAS.

Principal component analysis was used to determine the specific weight of the seven indicators in the scoring model. The formula for the quantitative score for RLAS was as follows: total score = 0.1473 × tumor size + 0.1264 × relationship of the tumor with the upper poles of the kidneys and renal hila + 0.1379 × the adhesion of PF + 0.1662 × relationship of the tumor with abdominal large blood vessels + 0.0291 × tumor CT enhancement + 0.2147 × relationship of the tumor with surrounding organs and tissues + 0.1784 × functional status of adrenal tumors.

Adrenal tumor growth was scored according to the scheme presented in *Figure 2*. The positional relationships were all derived from the CT data, which was followed by the calculation of the total score using the scoring models. For example, in *Figure 2C*, the total score was calculated as follows: total score = 0.1473 × 3 + 0.1264 × 3 + 0.1379 × PF + 0.1662 × 1 + 0.0291× tumor CT enhancement + 0.2147 × 3 + 0.1784 × functional status of adrenal tumors = (1.6314

Table 2 Multivariate ordinal logistic regression of the indicators for the OT and IBL

Parameters	OT				IBL			
	β value	P value	95% Wald CI		β value	P value	95% Wald CI	
			Lower	Upper			Lower	Upper
Tumor side	0.248	0.313	−0.265	0.761	−0.072	0.801	−0.629	0.486
Tumor size	0.582	0.030	0.056	1.108	0.457	0.086	−0.065	0.980
Relationships to the upper poles of the kidneys and the renal hila	0.808	0.001	0.383	1.234	0.278	0.198	−0.146	0.702
PF	0.966	0.001	0.549	1.384	0.441	0.038	0.025	0.857
Relationships to the large abdominal blood vessels	0.519	0.026	0.063	0.976	0.433	0.058	−0.015	0.880
Tumor CT enhancement	0.214	0.206	−0.118	0.547	0.271	0.132	−0.081	0.623
Relationships to the surrounding organs and tissues	−0.503	0.034	−0.968	−0.039	0.196	0.404	−0.265	0.658
Functional status of adrenal tumors	0.376	0.303	−0.340	1.092	1.144	0.001	0.457	1.831

OT, operative time; IBL, intraoperative blood loss; β, regression coefficient; CI, confidence interval; PF, periadrenal fat; CT, computed tomography.

+ 0.1379 × PF + 0.0291 × CT enhancement + 0.1784 × functional status of adrenal tumors) = 1.9768 scores (here the scores for PF, CT enhancement, and functional status of adrenal tumors are all assumed to be 1).

In *Figures 3*,*4*, two typical examples (*Figure 3* patient score =1.1379; *Figure 4* score =2.7925) illustrate the association between the scores and the CT scan characteristics of the tumor as well as the association between the scores and IBL (or OT).

Validation of the quantitative scoring model in predicting the OT, IBL, postoperative complications, and postoperative length of stay

The total scores were calculated using the aforementioned quantitative scoring models. Postoperative complications were graded using the Clavien-Dindo classification. Patients with Clavien-Dindo grade I complications were then assigned to the first group and those with Clavien-Dindo grade II–V into the second group. The correlation between the scores and OT, IBL, postoperative complications, and postoperative length were determined using Spearman correlation analysis. The total score had positive correlations with OT, IBL, and postoperative length of stay (all P values <0.001) but not with postoperative complications (P>0.05). The results of this analysis are presented in *Table 3*. As postoperative complications is a critical outcome in surgery, we calculated power (1 − β) to be 7.48% using G*Power 3.1.9.7 software; that is, there was only a 7.48% probability that a difference would detected if the difference indeed existed.

To further test the value of the quantitative scoring model for RLAS in predicting OT and IBL (two quantifiable major surgical outcomes), we performed ROC curve analysis. As presented in *Table 4*, ROC curve analysis demonstrated that the total score was better than any single metric for predicting the OT when it came to comparing an OT of >50 but ≤100 minutes with an OT of >100 but ≤150 minutes [area under the time-dependent ROC curve (AUC) =0.727; P<0.05]. In predicting an OT of >50 but ≤100 minutes or an OT of >100 but ≤150 minutes, total score (AUC =0.729; P<0.05) performed similarly to the relationship to large abdominal blood vessels (AUC =0.731; P<0.05), which performed better than did any other single metric for predicting the OT. Similarly, for IBL, the total score was better at predicting between group I (IBL ≤30 mL) and group II (IBL >30 but ≤100 mL) IBL (AUC =0.667; P<0.05) than any single metric (*Table 4*). For predicting between group II (IBL >30 but ≤100 mL) and group III (IBL >100 but ≤200 mL), the total score demonstrated adequate prediction ability (AUC =0.780; P<0.05) although it was inferior to the tumor size indicator (AUC =0.818; P<0.05).

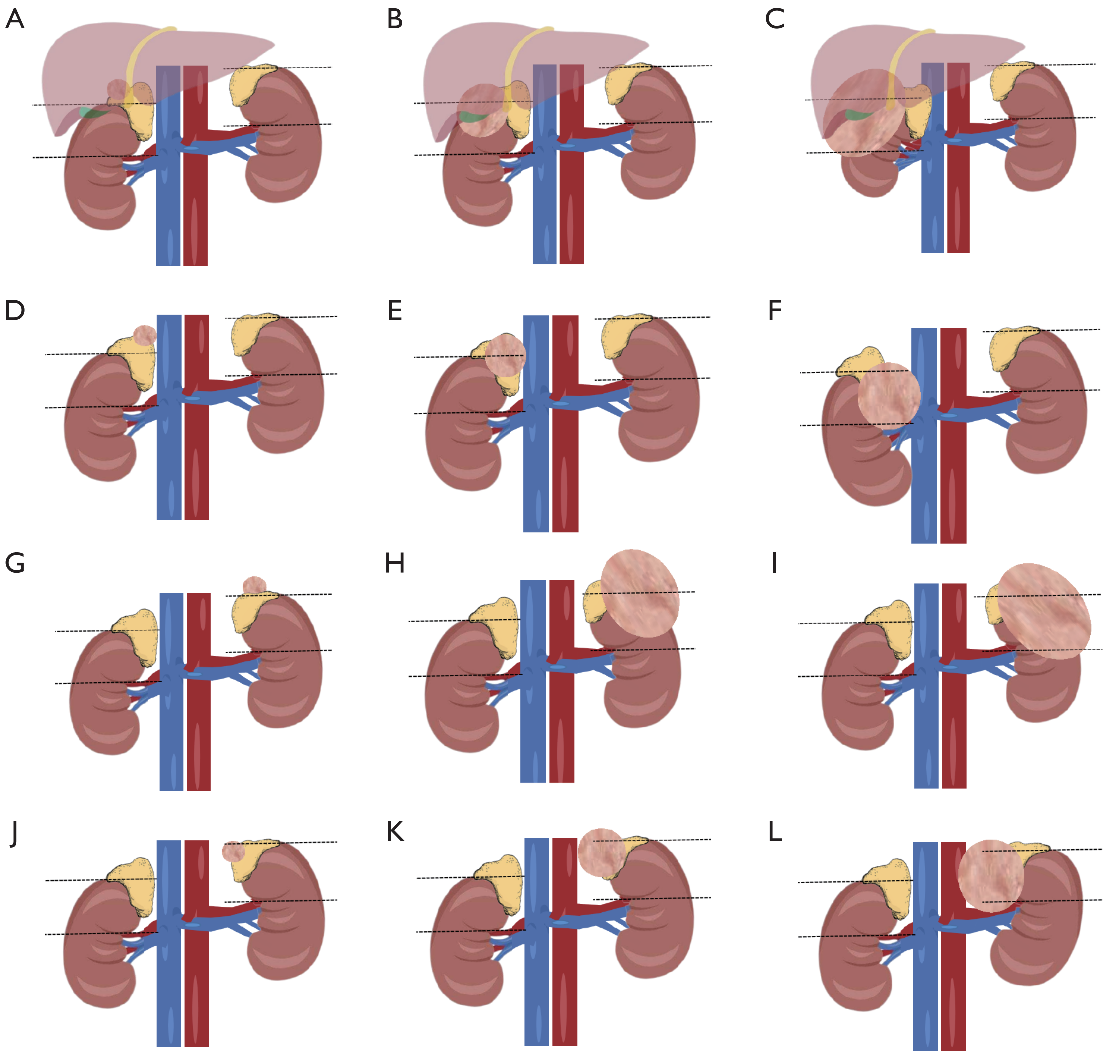

Figure 2 Adrenal tumor growth and scoring. Here, the score of the adhesion of PF, tumor CT enhancement, and functional status of adrenal tumors is each assumed to be 1. (A) TS =1. (B) TS =1.4884. (C) TS =1.9768. (D) TS =1. (E) TS =1.4399. (F) TS =2.3092. (G) TS =1. (H) TS =1.4210. (I) TS =1.5474. (J) TS =1. (K) TS =1.2737. (L) TS =1.9283. PF, periadrenal fat; CT, computed tomography; TS, total score.

A grading system for RLAS complexity based on the quantitative scoring model

Indeed, it was found that both OT and IBL differed significantly across all three grades (all P values <0.05; *Table 5*). The difference in postoperative length of stay significantly differed between grade I and grade III and between grade II and grade III (all P values <0.05) but not between grade I and grade II (P>0.05).

Consistency evaluation

Kappa analysis revealed that the scores of selected indicators (adrenal tumor size; relationships of the tumor with the upper poles of the kidneys and renal hila, abdominal large blood vessels, and the surrounding organs and tissues; tumor CT enhancement value; adhesion of PF) determined by the two surgeons had a high coincidence rate, indicating a high degree of consistency and repeatability between the two surgeons' scores (P<0.001; *Table 6*).

Discussion

Minimally invasive surgical treatment of adrenal tumors including laparoscopic surgery and robotic surgery has

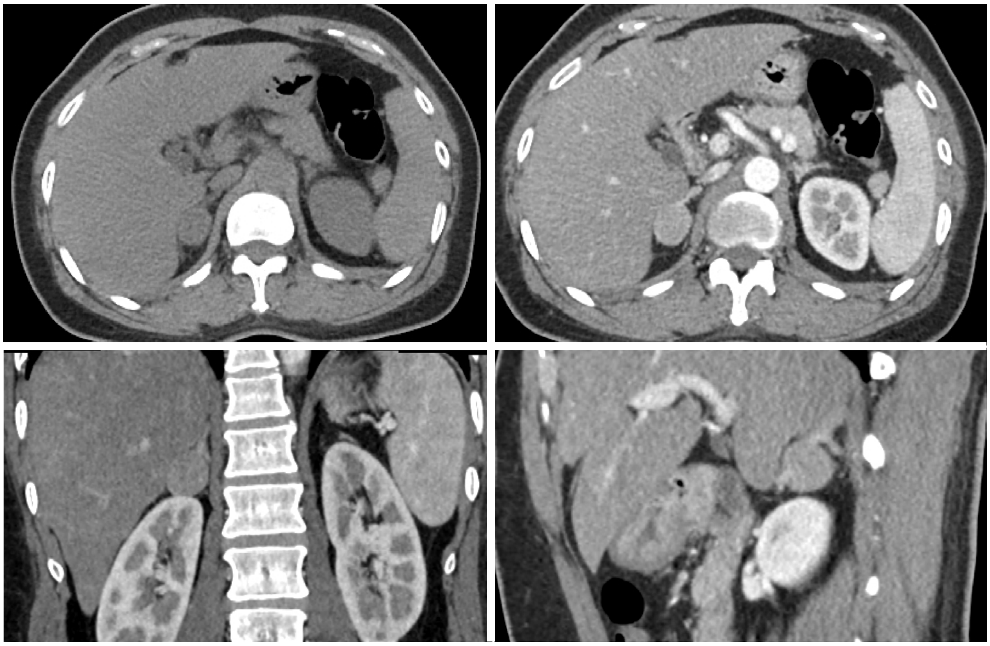

Figure 3 An example of a patient with right-sided nonfunctional adenoma. The scores of each indicator were as follows: tumor size, 1; relationship of the tumor with the upper poles of the kidney and the renal hila, 1; the adhesion of PF, 2; relationship of the tumor with abdominal large blood vessels, 1; tumor CT enhancement value, 1; relationship of the tumor with surrounding organs and tissues, 1; and functional status of adrenal tumors, 1. This patient's score was calculated as follows: 0.1473 × 1 + 0.1264 × 1 + 0.1379 × 2 + 0.1662 × 1 + 0.0291 ×1 + 0.2147 × 1 + 0.1784 × 1 = 1.1379. The values of the indicators were as follows: OT, 30 minutes; IBL, 30 mL; and grade II (moderate complexity and difficulty). PF, periadrenal fat; CT, computed tomography; OT, operative time; IBL, intraoperative blood loss.

become the standard surgical treatment for most small- to medium-sized adrenal tumors (25). Recent studies have indicated that the difficulty and risk of minimally invasive surgeries, such as posterior RLAS, are affected by factors including the complexity of the relationship between the tumor and the surrounding organs, the richness of the blood supply to the tumor, the distribution of blood vessels, and the endocrine function of the tumor itself (26-28). Therefore, it is important to develop an efficient and effective scoring model to assess the difficulty and risk of RLAS to efficiently guide clinical decision-making.

The adrenal glands and kidneys are located in the same perinephric space, and the adrenal glands partially overlap with the upper poles of the kidneys. Therefore, it is feasible to establish and validate a novel CT-based scoring model for adrenal tumors by referring to CT findings.

The findings of several studies highlight an issue regarding the maximal tumor diameter of retroperitoneoscopic adrenal tumor excision (29-32). As tumors increase in size, their contact surface with surrounding fat, surrounding organs, and other tissues likewise increases; that is, the area to be dissected and operative space increase accordingly, thereby increasing the operating time and difficulty of the operation. Prior studies have noted a significant correlation between the malignancy and diameter of adrenal tumors (33,34), and as malignant tumors tend to invade and adhere to the surrounding tissues, this also increases the difficulty of intraoperative separation and blood loss. Naya *et al.* (35) found that tumor size was an independent risk factor for longer OT and increased IBL. In our study, the tumor diameter nodes of 3 and 6 cm were selected, which is in line with previous reports, and tumor size was quantitatively scored. Our results indicated that increased tumor size was associated with an increase in OT. One of the advantages of this scoring model is that it provides a good indication of the progressive complexity of adrenal tumors by quantifying the relative location and characteristics of the tumor. In addition, the variable factors include the relationships of adrenal tumors with the surrounding organs and tissues and with large abdominal blood vessels. If adrenal tumors grow in the direction of the lateral extremity of the adrenal gland,

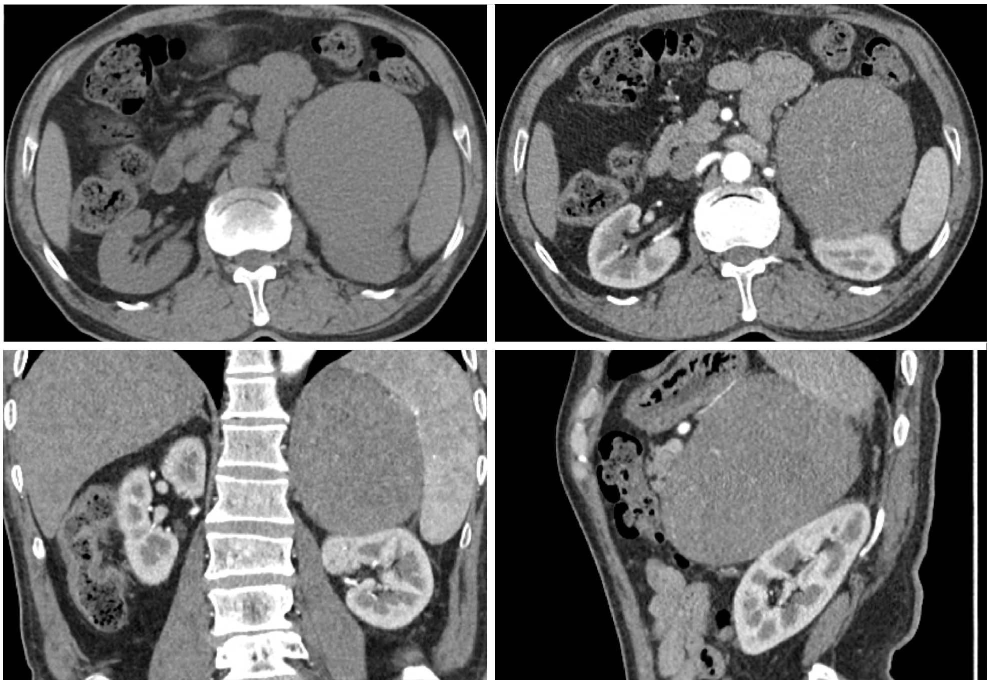

Figure 4 An example of a patient with left-sided aldosteronoma. The scores of each indicator were as follows, tumor size, 3; relationship of the tumor with the upper poles of the kidney and the renal hila, 3; the adhesion of PF, 3; the relationship of the tumor with abdominal large blood vessels, 3; tumor CT enhancement value, 2; the relationship of the tumor with the surrounding organs and tissues, 3; and functional status of adrenal tumors, 2. This male patient's score was calculated as follows: 0.1473 × 3 + 0.1264 × 3 + 0.1379 × 3 + 0.1662 × 3 + 0.0291 × 2 + 0.2147 × 3 + 0.1784 × 2 = 2.7925. The values of the indicators were as follows: OT, 120 minutes; IBL, 400 ml; and grade III (high complexity and difficulty). PF, periadrenal fat; CT, computed tomography; OT, operative time; IBL, intraoperative blood loss.

Table 3 Correlation of total score with the OT, IBL, postoperative complications, and postoperative length of stay

Parameters	OT		IBL		Postoperative complications				Postoperative length of stay	
	r_s	P value	r_s	P value	r_s	P value	$Z^{\dagger}$	$P^{\dagger}$value	r_s	P value
Total score	0.431	0.001	0.446	0.001	0.165	0.392	−0.240	0.811	0.180	0.002

†, Mann-Whitney rank-sum test. OT, operative time; IBL, intraoperative blood loss; r_s, Spearman rank correlation coefficient.

the tumors will not compress the large vessels. Conversely, if the tumors grow in the direction of the medial extremity, they tend to compress the large vessels, kidneys, and surrounding organs and tissues due to the limited space.

Fouche *et al.* (36) found that an increase in body mass index (BMI) was associated with a longer duration of laparoscopic adrenal tumor surgery, while Manno *et al.* (37) reported that obesity is positively correlated with visceral fat including periadrenal and perirenal fat. According to the literature, PF volume appears to be a better predictor of OT in RLAS than is BMI (11,38). Davidiuk *et al.* created the MAP score, an image-based scoring system for kidney surgery, which is based on adherent PF (4). Overall, it is more intuitive and accurate to use CT imaging of PF than it is to use BMI. In this study, whether cord-like changes occurred in PF and the degree of these changes were assigned numerical scores. Surprisingly, we found that PF had the greatest impact on OT.

Previous studies reported a sensitivity and specificity of adrenal tumor diagnosis of 71% and 98% at ≤10 HU on unenhanced CT, respectively; however, this method could not clarify whether the adrenal tumors had endocrine function (21,22). A CT value of 11–30 HU can indicate that the lesion is an adenoma with some lipid content,

Table 4 The results of ROC curve analysis for OT and IBL

Parameters	OT						IBL					
	Group I *vs.* II		Group II *vs.* III		Group III *vs.* IV		Group I *vs.* II		Group II *vs.* III		Group III *vs.* IV	
	AUC	P value	AUC	P value	AUC	P value	AUC	P value	AUC	P value	AUC	P value
Total score	0.588	0.132	0.727	0.001	0.729	0.003	0.667	0.001	0.780	0.004	0.531	0.762
Tumor size	0.574	0.208	0.641	0.001	0.671	0.024	0.551	0.251	0.818	0.001	0.483	0.868
Relationships to the upper poles of the kidneys and the renal hila	0.539	0.501	0.639	0.001	0.696	0.010	0.541	0.356	0.719	0.023	0.467	0.750
PF	0.562	0.292	0.717	0.001	0.627	0.095	0.611	0.012	0.646	0.128	0.528	0.785
Relationships to the large abdominal blood vessels	0.507	0.906	0.610	0.009	0.731	0.002	0.534	0.446	0.718	0.023	0.566	0.525
Tumor CT enhancement	0.474	0.658	0.582	0.049	0.617	0.124	0.587	0.048	0.502	0.986	0.589	0.388
Relationships to the surrounding organs and tissues	0.554	0.359	0.619	0.005	0.579	0.296	0.619	0.007	0.594	0.005	0.547	0.650
Functional status of adrenal tumors	0.536	0.541	0.589	0.033	0.594	0.216	0.573	0.096	0.616	0.227	0.549	0.639

OT of group I, ≤50 min; OT of group II, >50 but ≤100 min; OT of group III, >100 but ≤150 min; OT of group IV, >150 min. IBL of group I, ≤30 mL; IBL of group II, >30 mL but ≤100 mL; IBL of group III, >100 mL but ≤200 mL; IBL of group IV, >200 mL. ROC, receiver operating characteristic; OT, operative time; IBL, intraoperative blood loss; AUC, area under the time-dependent ROC curve; PF, periadrenal fat; CT, computed tomography.

Table 5 The correlation of the grading system based on the quantitative scoring model with OT, IBL, and postoperative length of stay according to the Kruskal-Wallis test

Parameters	OT		IBL		Postoperative length of stay	
	H value	P value	H value	P value	H value	P value
Grade I *vs.* grade II	61.360	0.001	44.471	0.046	14.157	1.000
Grade I *vs.* grade III		0.001		0.001		0.007
Grade II *vs.* grade III		0.001		0.001		0.001

OT, operative time; IBL, intraoperative blood loss.

Table 6 The results of kappa analysis for the two observers

Parameters	Consistency rate (%)	κ value	P value
Tumor size	96.1	0.915	0.001
Relationships to the upper poles of the kidneys and the renal hila	94.4	0.880	0.001
PF	86.0	0.751	0.001
Tumor CT enhancement	87.9	0.811	0.001
Relationships to the large abdominal blood vessels	95.8	0.892	0.001
Relationships to the surrounding organs and tissues	93.8	0.892	0.001

PF, periadrenal fat; CT, computed tomography.

whereas with a CT value of ≥30 HU, the lesion may be a pheochromocytoma or malignant tumor (21). The change of the CT value before and after CT enhancement is <20 HU for benign tumors and >20 HU for malignant tumors (23,24). In other words, CT values can likely be used to diagnosis adrenal tumors. Therefore, in this study, the indicators in the model were quantified according to CT data, and the tumor CT enhancement value was included in the scoring model.

In this study, after certain factors, including PF and the relationship of the tumor with surrounding organs and tissues, were incorporated into the multivariate ordinal logistic regression model and after confounders were controlled for, the relationship between adrenal tumors and surrounding organs and tissues was found to be a predictor of shorter OT (*Table 2*). A possible explanation for this might be related to the operative space. Several studies have reported that a relatively small operating space increases the difficulty of posterior laparoscopic adrenalectomy (11,38,39). Adrenal tumors compress and displace surrounding organs and tissues when they grow without fat saponification or adhesions, which increases the operative space and makes it relatively easier to find and excise the tumors.

A scoring model should be evaluated from several aspects. First, the score should be easy to measure and calculate, and the indicators of the model should not be complex; otherwise, the measurements will be time-consuming for raters (5,7,40). Fortunately, in this study, only the tumor size needed to be calculated, and other indicator scores could be quickly and accurately obtained from CT data. The functional status of adrenal tumors could be scored based on the clinical diagnosis derived from the endocrinological and radiological data. Second, the model should be consistent; that is, different evaluators should produce similar results (41,42). Finally, the model should be stable and repeatable (6,7,41). The results of the kappa test in this study indicated that the model scores had good consistency and repeatability when independently calculated by two surgeons. The results revealed that seven indicators were associated with both OT and IBL. These indicators were incorporated to establish the quantitative scoring model for RLAS. The model had a high degree of fit with both OT and IBL. Moreover, both the scoring model and its scoring model-based grading system for complexity and difficulty of RLAS had positive correlations with OT, IBL, and postoperative length of stay. Therefore, this scoring model based on CT image data can be applied to predict the perioperative outcomes of RLAS and help surgeons more precisely understand the complexity and difficulty of RLAS. Hence, in those patients who likely require highly complex and challenging RLAS, better emergencies plans and preoperative measures could be made, for example, preoperative blood preparation, preoperative reminder to anesthetists of risk, more elaborate intraoperative manipulation, and targeted postoperative management for preventing severe complications. Furthermore, the scoring model could potentially function as a reliable assessment system in the development of a risk-stratified adrenalectomy training project aimed at training young surgeons and as a tool for assisting in the efficient communication between doctors and patients.

This study had several limitations. First, the clinical data were analyzed retrospectively. Second, the results assessing the relationships between adrenal tumors and surrounding organs and tissues were susceptible to variability. For instance, the degree of adhesion and compression of the liver by right adrenal tumors and those of the peritoneum by left adrenal tumors are difficult to determine. Third, the repeatability of the scores between urologists and radiologists was not always acceptable for the classical renal tumor scoring system (42). The developed scoring model is similar to the classical renal tumor scoring system based on CT data. Although both raters were experienced in reading CT images, deviation was inevitable. For instance, the judgment of PF adhesion and saponification and the calculation of CT enhancement for partially necrotic tumors inevitably involves some subjectivity. Fourth, in determining whether this model could perform well in predicting the risk of RLAS, the scoring model was not validated in circumstances where young or inexperienced surgeons were calculating the scores. When this scoring model is used in clinical practice by an inexperienced surgeon, the ability to identify the valuable CT imaging data is critical to implementing this model properly. If applied in the correct manner, the quantitative scoring model based on CT images should be more useful for inexperienced surgeons in preoperatively assessing the RLAS difficulty. Moreover, the scoring model could potentially function as a reliable assessment system in developing a risk-stratified RLAS training program for inexperienced surgeons, for whom guidance by experienced surgeons is particularly needed. Fifth, this study only examined the application of this scoring model in RLAS for adrenal tumors, and its utility for open surgery or laparoscopic surgery via the transperitoneal approach was not assessed, thereby limiting the universality of this scoring system. Finally, the sample size of postoperative complications was too small to further analyze the relationship between postoperative complications and the scoring system. In this study, the scoring model did not differ significantly according to the presence of postoperative complications (P>0.05; *Table 3*). However, the power was only 7.48%; thus, there is only a 7.48% probability that a difference would be detected if it indeed existed. Thus, further prospective multicenter studies with larger sample sizes should be conducted to validate our findings of the relationship between postoperative complications and the scoring system.

Conclusions

We developed a scoring model that incorporated indicators of the adrenal tumor size; the relationships of the tumor with the upper poles of the kidneys and renal hila, the surrounding organs and tissues, and the large abdominal vessels; the adhesion of PF; the tumor CT enhancement value; and the functional status of adrenal tumors. Under specific weighting of these indicators, the scoring model for RLAS demonstrated consistency, stability, and repeatability in predicting the difficulty and complexity of surgery and thus has valuable clinical utility.

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Footnote

Reporting Checklist: The authors have completed the TRIPOD reporting checklist. Available at https://qims.amegroups.com/article/view/10.21037/qims-23-764/rc

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-764/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. This retrospective study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and was approved by the Ethics Committee of the First Affiliated Hospital of Fujian Medical University (approval No. MTCA, ECFAH of FMU [2015]084-1). The requirement for informed consent was waived due to the retrospective nature of the study.

References

1. Yeo CT, Pasieka JL, Assadzadeh GE, Harvey A. The adoption of the endoscopic retroperitoneal approach to the adrenal gland - Conversion factors and learning points. Am J Surg 2022;224:703-9.
2. Barczyński M, Konturek A, Nowak W. Randomized clinical trial of posterior retroperitoneoscopic adrenalectomy versus lateral transperitoneal laparoscopic adrenalectomy with a 5-year follow-up. Ann Surg 2014;260:740-7; discussion 747-8.
3. Arezzo A, Bullano A, Cochetti G, Cirocchi R, Randolph J, Mearini E, Evangelista A, Ciccone G, Bonjer HJ, Morino M. Transperitoneal versus retroperitoneal laparoscopic adrenalectomy for adrenal tumours in adults. Cochrane Database Syst Rev 2018;12:CD011668.
4. Davidiuk AJ, Parker AS, Thomas CS, Leibovich BC, Castle EP, Heckman MG, Custer K, Thiel DD. Mayo adhesive probability score: an accurate image-based scoring system to predict adherent perinephric fat in partial nephrectomy. Eur Urol 2014;66:1165-71.
5. Kutikov A, Uzzo RG. The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. J Urol 2009;182:844-53.
6. Ficarra V, Novara G, Secco S, Macchi V, Porzionato A, De Caro R, Artibani W. Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for nephron-sparing surgery. Eur Urol 2009;56:786-93.
7. Simmons MN, Ching CB, Samplaski MK, Park CH, Gill IS. Kidney tumor location measurement using the C index method. J Urol 2010;183:1708-13.
8. Shonkwiler RJ, Lee JA. Laparoscopic retroperitoneal

adrenalectomy. Surg Laparosc Endosc Percutan Tech 2011;21:243-7.

9. Ottlakan A, Paszt A, Simonka Z, Abraham S, Borda B, Vas M, Teleky B, Balogh A, Lazar G. Laparoscopic transperitoneal and retroperitoneal adrenalectomy: a 20-year, single-institution experience with an analysis of the learning curve and tumor size [lap transper and retroper adrenalectomy]. Surg Endosc 2020;34:5421-7.
10. Raffaelli M, De Crea C, Bellantone R. Laparoscopic adrenalectomy. Gland Surg 2019;8:S41-52.
11. Rah CS, Kim WW, Lee YM, Chung KW, Koh JM, Lee SH, Hong SJ, Sung TY. New predictive factors for prolonged operation time of laparoscopic posterior retroperitoneal adrenalectomy; retrospective cohort study. Int J Surg 2021;94:106113.
12. Fassnacht M, Kenn W, Allolio B. Adrenal tumors: how to establish malignancy ? J Endocrinol Invest 2004;27:387-99.
13. Cyranska-Chyrek E, Szczepanek-Parulska E, Olejarz M, Ruchala M. Malignancy Risk and Hormonal Activity of Adrenal Incidentalomas in a Large Cohort of Patients from a Single Tertiary Reference Center. Int J Environ Res Public Health 2019;16:1872.
14. Iñiguez-Ariza NM, Kohlenberg JD, Delivanis DA, Hartman RP, Dean DS, Thomas MA, Shah MZ, Herndon J, McKenzie TJ, Arlt W, Young WF Jr, Bancos I. Clinical, Biochemical, and Radiological Characteristics of a Single-Center Retrospective Cohort of 705 Large Adrenal Tumors. Mayo Clin Proc Innov Qual Outcomes 2018;2:30-9.
15. Macleod LC, Hsi RS, Gore JL, Wright JL, Harper JD. Perinephric fat thickness is an independent predictor of operative complexity during robot-assisted partial nephrectomy. J Endourol 2014;28:587-91.
16. Wallis CJD, Saskin R, Choo R, Herschorn S, Kodama RT, Satkunasivam R, Shah PS, Danjoux C, Nam RK. Surgery Versus Radiotherapy for Clinically-localized Prostate Cancer: A Systematic Review and Meta-analysis. Eur Urol 2016;70:21-30.
17. Kocher NJ, Kunchala S, Reynolds C, Lehman E, Nie S, Raman JD. Adherent perinephric fat at minimally invasive partial nephrectomy is associated with adverse peri-operative outcomes and malignant renal histology. BJU Int 2016;117:636-41.
18. Gupta PK, Natarajan B, Pallati PK, Gupta H, Sainath J, Fitzgibbons RJ Jr. Outcomes after laparoscopic adrenalectomy. Surg Endosc 2011;25:784-94.
19. Conzo G, Pasquali D, Colantuoni V, Circelli L, Tartaglia E, Gambardella C, Napolitano S, Mauriello C, Avenia N, Santini L, Sinisi AA. Current concepts of pheochromocytoma. Int J Surg 2014;12:469-74.
20. Hauch A, Al-Qurayshi Z, Kandil E. Factors associated with higher risk of complications after adrenal surgery. Ann Surg Oncol 2015;22:103-10.
21. Bednarczuk T, Bolanowski M, Sworczak K, Górnicka B, Cieszanowski A, Otto M, Ambroziak U, Pachucki J, Kubicka E, Babińska A, Koperski Ł, Januszewicz A, Prejbisz A, Górska M, Jarząb B, Hubalewska-Dydejczyk A, Glinicki P, Ruchała M, Kasperlik-Załuska A. Adrenal incidentaloma in adults - management recommendations by the Polish Society of Endocrinology. Endokrynol Pol 2016;67:234-58.
22. Low G, Dhliwayo H, Lomas DJ. Adrenal neoplasms. Clin Radiol 2012;67:988-1000.
23. Berland LL, Koslin DB, Kenney PJ, Stanley RJ, Lee JY. Differentiation between small benign and malignant adrenal masses with dynamic incremented CT. AJR Am J Roentgenol 1988;151:95-101.
24. Korobkin M, Brodeur FJ, Yutzy GG, Francis IR, Quint LE, Dunnick NR, Kazerooni EA. Differentiation of adrenal adenomas from nonadenomas using CT attenuation values. AJR Am J Roentgenol 1996;166:531-6.
25. Sada A, McKenzie TJ. Surgical approaches to the adrenal gland. Curr Opin Endocrinol Diabetes Obes 2023;30:161-6.
26. Sherlock M, Scarsbrook A, Abbas A, Fraser S, Limumpornpetch P, Dineen R, Stewart PM. Adrenal Incidentaloma. Endocr Rev 2020;41:775-820.
27. Hu D, Zhu D, Zhang Y, Wang X. Experience in identifying the variant adrenal venous anatomy during modified retroperitoneoscopic adrenalectomy. J Minim Access Surg 2021;17:175-9.
28. Kook Y, Choi HR, Kang SW, Kim JK, Lee CR, Lee J, Jeong JJ, Nam KH, Chung WY. Laparoscopic adrenalectomy: comparison of outcomes between posterior retroperitoneoscopic and transperitoneal adrenalectomy with 10 years' experience. Gland Surg 2021;10:2104-12.
29. Prudhomme T, Roumiguié M, Gas J, Soulié M, Thoulouzan M, Huyghe E. Comparison between retroperitoneal and transperitoneal laparoscopic adrenalectomy: Are both equally safe? J Visc Surg 2021;158:204-10.
30. Myśliwiec P, Marek-Safiejko M, Lukaszewicz J, Safiejko K, Kozlowski R, Wojskowicz P, Dadan J. Videoscopic adrenalectomy - when does retroperitoneal seem better? Wideochir Inne Tech Maloinwazyjne 2014;9:226-33.
31. Chung HS, Kim MS, Yu HS, Hwang EC, Kim SO, Oh

KJ, Jung SI, Kang TW, Park K, Kwon DD. Laparoscopic adrenalectomy using the lateral retroperitoneal approach: Is it a safe and feasible treatment option for pheochromocytomas larger than 6 cm? Int J Urol 2018;25:414-9.
32. Grozdev K, Khayat N, Shumarova S, Ivanova G, Angelov K, Todorov G. Lateral retroperitoneoscopic adrenalectomy: advantages and drawbacks. Updates Surg 2020;72:1151-7.
33. Park SY, Park BK, Park JJ, Kim CK. CT sensitivities for large (≥3 cm) adrenal adenoma and cortical carcinoma. Abdom Imaging 2015;40:310-7.
34. Patrova J, Jarocka I, Wahrenberg H, Falhammar H. Clinical outcomes in adrenal incidentaloma: experience from one center. Endocr Pract 2015;21:870-7.
35. Naya Y, Suzuki H, Komiya A, Nagata M, Tobe T, Ueda T, Ichikawa T, Igarashi T, Yamaguchi K, Ito H. Laparoscopic adrenalectomy in patients with large adrenal tumors. Int J Urol 2005;12:134-9.
36. Fouche D, Chenais G, Haissaguerre M, Bouriez D, Gronnier C, Collet D, Tabarin A, Najah H. Risk factors for intraoperative complications, postoperative complications, and prolonged length of stay after laparoscopic adrenalectomy by transperitoneal lateral approach: a retrospective cohort study of 547 procedures. Surg Endosc 2023;37:7573-81.
37. Manno C, Campobasso N, Nardecchia A, Triggiani V, Zupo R, Gesualdo L, Silvestris F, De Pergola G. Relationship of para- and perirenal fat and epicardial fat with metabolic parameters in overweight and obese subjects. Eat Weight Disord 2019;24:67-72.
38. Pearlstein SS, Kuo JH, Chabot JA, Lee JA. Periadrenal Volume is a Better Predictor of Prolonged Operative Time in Laparoscopic Retroperitoneal Adrenalectomy than BMI. World J Surg 2020;44:578-84.
39. Christakis I, Ng CS, Chen C, Yiin YH, Grubbs EG, Perrier ND, Lee JE, Graham PH. Operation duration and adrenal gland size, but not BMI, are correlated with complication rate for posterior retroperitoneoscopic adrenalectomy for benign diseases. Surgery 2019;165:637-43.
40. Zhang S, Qin Z, Bi H, Tao L, Zhang F, Zhang H, Wang W, Wu J, Huang Y, Ma L. A "3S+f" Nephrometry Score System to Predict the Clinical Outcomes of Laparoscopic Nephron-Sparing Surgery. Front Oncol 2022;12:922082.
41. Tatenuma T, Ito H, Muraoka K, Ito Y, Hasumi H, Hayashi N, Kondo K, Nakaigawa N, Makiyama K. Roughness of the renal tumor surface could predict the surgical difficulty of robot-assisted partial nephrectomy. Asian J Endosc Surg 2022;15:591-8.
42. Benadiba S, Verin AL, Pignot G, Bessede T, Drai J, Bahi R, Toussile W, Rocher L, Patard JJ. Are urologists and radiologists equally effective in determining the RENAL Nephrometry score? Ann Surg Oncol 2015;22:1618-24.

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