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Relationship between surgical difficulty and postoperative complications of hand-assisted laparoscopic living donor nephrectomy and establishment of prediction model

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Abstract

Background Few studies have systematically explored the factors influencing the difficulty of hand-assisted laparoscopic living donor nephrectomy. To investigate the relationship between the difficulty of hand-assisted laparoscopic living donor nephrectomy and postoperative complications of the donor as well as the recipient, and then build a model for predicting the difficulty of surgery.

Methods In this study, 60 patients who underwent hand-assisted laparoscopic living donor nephrectomy by the same surgeon from September 2022 to March 2024 were included as the modeling group. 20 patients operated on by another surgeon served as the external validation group. The subjective score (1–3 points) of surgical difficulty was used as the quantitative index of surgical difficulty. Pearson and Spearman correlation tests were used to explore the correlation between preoperative data and surgical difficulty scores of kidney donors, and finally built a prediction model through multiple linear regression analysis.

Results With the increase in the difficulty of operation, both donors and recipients' complications were increased. Linear regression analysis showed that only the number of renal arteries, visceral fat thickness and MAP score were independent risk factors for the difficulty of hand-assisted laparoscopic living donor nephrectomy. The prediction equation is as follows: Difficulty score = 0.584*Number of renal arteries + 0.731*MAP score + 0.110*visceral fat thickness.

Conclusions Donors with higher surgical difficulty are more likely to have serious complications after surgery as well as the recipient. We also established a reliable prediction model for the difficulty of hand-assisted laparoscopic donor nephrectomy.

Keywords Living donor nephrectomy, Speed-limiting steps, Complication, Operative difficulty

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Background

Allograft kidney transplantation is the only surgical treatment for patients with end-stage renal disease. Compared with organ donation after the death of a citizen, the cold ischemia time of a living donor kidney is shorter, and the preoperative preparation time is relatively sufficient [1, 2], which makes the survival rate of the grafts after living donor kidney surgery higher and the long-term function of grafts better. However, for donors, living donor nephrectomy is a non-beneficial operation, so the question of how to minimize the pain of donor surgery and reduce postoperative complications has gradually been receiving attention by transplant doctors. Compared with traditional laparoscopic surgery, hand-assisted laparoscopic kidney donor extraction combines minimally invasive methods with the fine tactile feedback of the hand. Compared to the emerging robot-assisted laparoscopic retroperitoneal donor nephrectomy, hand-assisted laparoscopic nephrectomy is more appropriate for kidney transplant populations in developing countries because of its lower cost and safety demonstrated by large-scale studies [3, 4]. With the direct assistance and protection of the hand, the surgeon can clamp and disconnect the donor blood vessels more accurately and quickly, while minimizing intraoperative damage to the donor kidney, blood vessels, and their surrounding tissues. Thus, the warm ischemia time of a kidney donor is shortened and postoperative complications are reduced [5–7]. Although hand-assisted laparoscopic kidney donor extraction is almost routine, due to the small operating space in the posterior abdominal cavity and the requirement for the surgeon to complete kidney acquisition as soon as possible without damaging the kidney and preserving sufficient length of blood vessels, hand-assisted laparoscopic kidney donor extraction is significantly more difficult than radical kidney surgery and other operations, especially for young doctors. This often leads to prolonged warm ischemia time of the graft, affects the transplant effect, and may even increase the incidence and severity of postoperative complications of the donor.

The accurate prediction of the difficulty of surgery prior to surgery will help the clinical selection of suitable surgeons, and play a role in training young doctors on the basis of completing the operation safely and efficiently. However, few studies have systematically explored the factors influencing the difficulty of hand-assisted laparoscopic living donor nephrectomy. In previous studies, surgical time or intraoperative blood loss were mostly used as alternative indicators of surgical difficulty [8–11]. However, whether these indicators can directly and accurately replace the difficulty of surgery remains to be discussed. Therefore, in this paper, the subjective score of surgical difficulty was used as the quantitative standard of surgical difficulty, and a preoperative prediction model was constructed, in order to help the clinic select the right surgeon before obtaining the kidney donor, and make the surgeon more targeted in preparation for complex cases.

Method and material

Research object

A total of 80 donors who underwent hand-assisted laparoscopic living donor kidney resection at Beijing Friendship Hospital, Capital Medical University from September 2022 to March 2024 were selected by a retrospective study (60 cases in the modeling group and 20 cases in the external verification group). This study complies with the Declaration of Helsinki and is approved by the Ethics Committee of our hospital. All subjects have signed informed consent, and the batch number is: BFHHZS20240073.

Inclusion and exclusion criteria

Inclusion criteria: (1) The operators in the modeling group and the external validation group are the same, but the operators between the groups are different. Exclusion criteria: (1) The operation time was affected by drug allergy or other conditions during the operation; (2) Lack of preoperative CT images, partial laboratory results or other examinations leads to incomplete medical records. (3) Preoperative lithiasis was found in the donor kidney.

Surgical methods

We adopted an improved hand-assisted retrolaparoscopy technique consistent with previous studies [11]. The main improvements include: (1) The combination of blunt separation and sharp scissors separation was used for kidney removal, and the intermittent hemostasis was performed by an ultrasonic knife. (2) After the renal artery, vein and ureter were fully free, the surgeon made a parallel rectus abdominalis incision in the lateral abdomen and entered the retroperitoneal space to re-establish the pneumoperitoneum. (3) The surgeon moderately pulled the renal artery and vein with his left hand, and then used 2 Hem-o-lock clamps on the proximal end of the renal artery and vein successively, and directly removed the kidney donor after cutting the renal artery and vein with scissors.

Observation indicators

The subjective difficulty score of each hand-assisted laparoscopic living donor nephrectomy was recorded, and the whole operation was divided into the following four main steps: Trocar placement, separating the renal hilum, separating the perinephric region and kidney removal, and the time consumption of different steps were recorded respectively. Demographic data and perioperative clinical data were also collected, including gender, age, BMI, underlying diseases, smoking history,

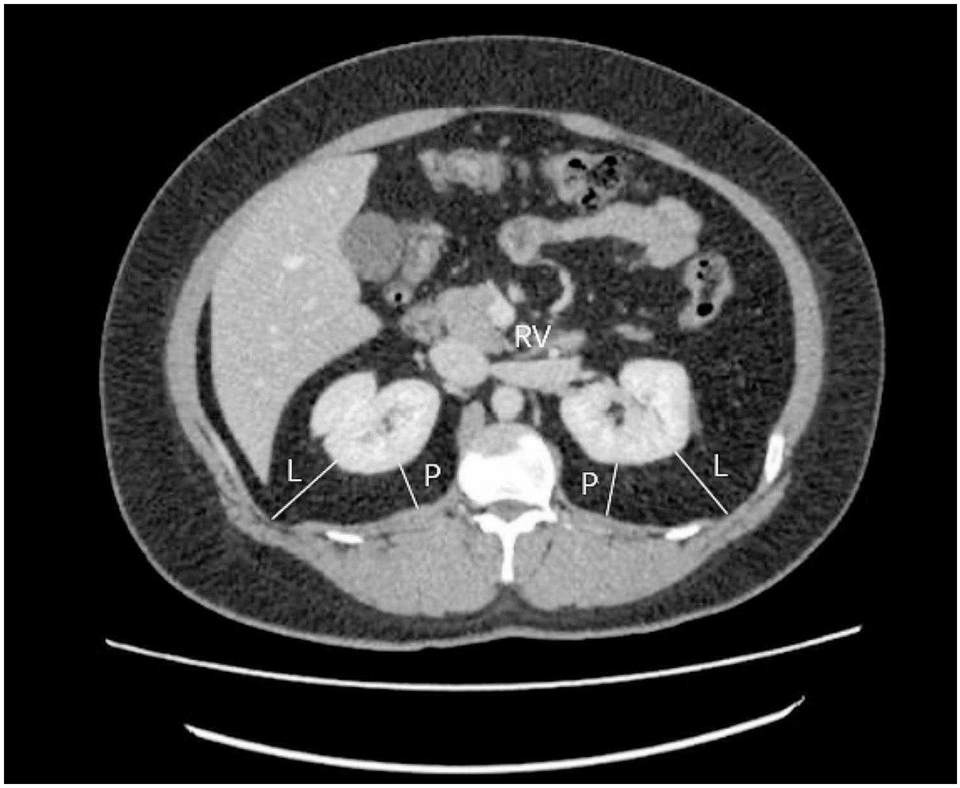

Fig. 1 Measurement of perirenal and postrenal fat thickness. RV = renal vein. L = perirenal fat thickness. P = postrenal fat thickness

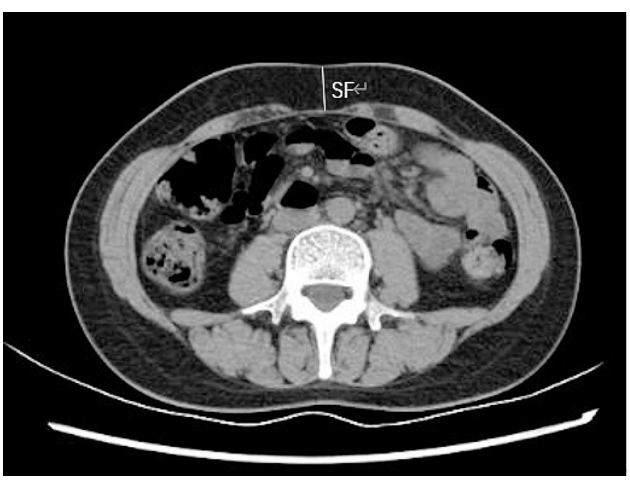

Fig. 2 Measurement of subcutaneous fat thickness. SF = subcutaneous fat thickness

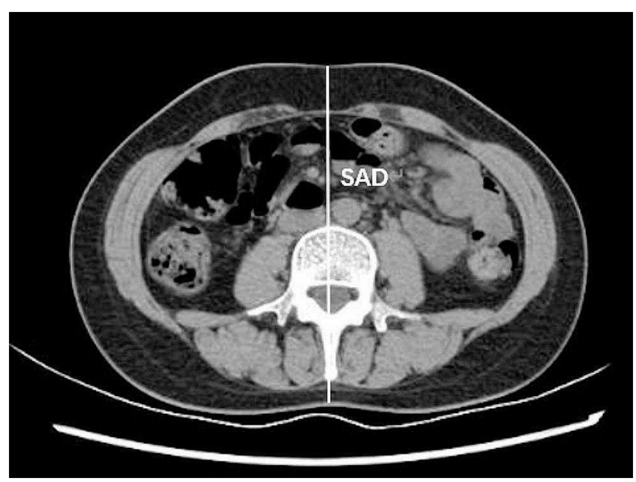

Fig. 3 Measurement of sagittal abdominal diameter. SAD = sagittal abdominal diameter

history of abdominal surgery, left side of the surgery, anatomical anomaly, preoperative blood lipid level, ASA score, postoperative hospitalization days, drainage tube retention time, pain visual analogue scale(VAS), etc. Meanwhile, in this study, donor kidney length, width, thickness, and volume, the number of renal arteries, the number of donor renal veins, perirenal fat thickness [12, 13] (see Fig. 1 for measurement methods), subcutaneous fat thickness (see Fig. 2 for measurement methods), and Mayo adhesive probability score were also included [12], sagittal abdominal diameter (see Fig. 3 for measurement method), distance of the 12th rib - iliac crest (see Fig. 4 for measurement method), distance of the 12th rib - the 12th rib (see Fig. 4 for measurement methods), transverse pelvic diameter [14] (see Fig. 4 for measurement methods), Agatston score of renal artery calcification [15], etc. Among them, the subjective difficulty score was used to score the overall difficulty of surgery after surgery

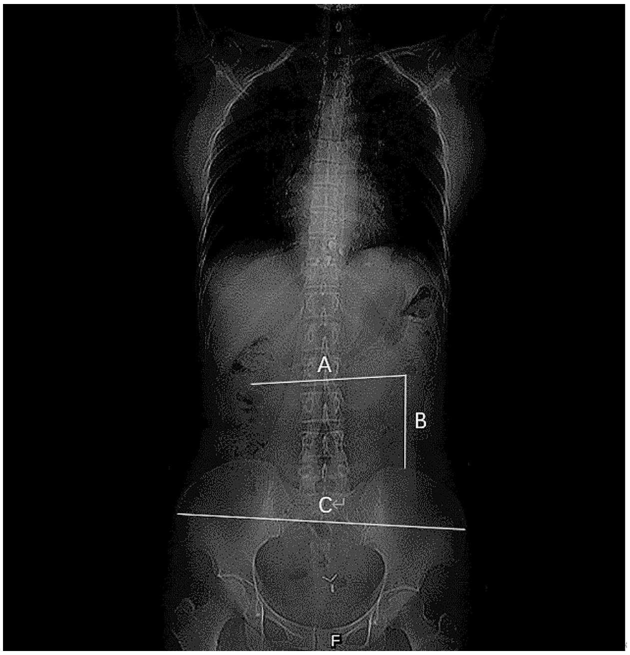

Fig. 4 Measurement of the 12th rib - the 12th rib, transverse pelvic diameter and the 12th rib – iliac crest. A=The 12th rib - the 12th rib. B=The 12th rib – iliac crest. C=Transverse pelvic diameter

(1–3 points), and the higher the score, the more difficult the surgery was.

Statistical methods

SPSS 25.0 software was used to analyze and process the research data. For comparison between groups of quantitative data, Bonferroni method was used for multiple comparisons if the data met the normal distribution, and Kruskal-Wallis multiple local rank sum test was used if the data did not meet the normal distribution. Chi-square test and Fisher's exact probability method were used for the comparison of multi-group rates and composition ratios. α segmentation method was used for the multiple comparison of Chi-square test, that is, R*C cross table was divided into n 2*2 four-cell tables, and the test level α became α/n. In terms of influencing factors of surgical difficulty, quantitative data consistent with normal distribution were presented as mean ± standard deviation ($x \pm s$), and Pearson correlation test was used for analysis. The classified data is expressed as an example (%). Quantitative data that did not conform to normal distribution were expressed as the median (interquartile distance) [M(Q1,Q3)], and Spearman correlation test was used for classified data or quantitative data that did not conform to normal distribution. With the difficulty of surgery as the dependent variable and the above influencing factors as the independent variables, bivariate correlation analysis was carried out, and all the variables with statistically significant differences were included in the multifactor linear regression analysis, so as to obtain the prediction equation of the difficulty of surgery.

Then, the model is verified internally and externally to evaluate its accuracy. In internal verification, 100 patients in the modeling group were selected by random number table method, and their predicted surgical difficulty was calculated by regression equation, and paired T-test was performed with the actual value. An additional 20 patients with laparoscopic donor nephrectomy assisted by another surgeon were collected as an external validation set. The prediction of surgical difficulty was calculated by regression equation, and paired T-test was performed with the actual value. With the exception of α segmentation, all test methods were considered statistically significant with $P < 0.05$.

Result

Correlation between surgical difficulty and postoperative complications

Among the 60 patients in the modeling group, 31 donors had a surgery difficulty of 1 point, of which 30 and 1 had Clavien-Dindo grade 1 and 2, respectively. There were 23 donors with a 2 points of surgical difficulty, of which 16 were Clavien-Dindo grade 1 and 7 were Clavien-Dindo grade 2. Among the 6 donors with a surgical difficulty of 3, 3 had Clavien-Dindo grade 1 and 3 had Clavien-Dindo grade 2. Among them, there was a statistical difference in the severity of complications between the group with difficulty 1 and the group with difficulty 2 or 3 ($P < 0.05$). However, there were no statistical differences between each group in Clavien-Dindo grade and incidence of postoperative delayed graft function (DGF) in recipients. At the same time, there were also statistical differences in intraoperative blood loss, postoperative catheter retention time, and hospital stay for donors among different surgical difficulty groups ($P < 0.05$) (Table 1).

Rate-limiting step analysis of hand-assisted laparoscopic living donor nephrectomy

In this study, hand-assisted laparoscopic living donor nephrectomy was divided into four main steps: Trocar placement, separating the renal hilum, separating the perinephric region and kidney removal. In all groups of surgical difficulty, the time required to separate the renal hilum was much higher than the other steps (Table 2). At the same time, as the difficulty of the operation increased, the time of Trocar placement, separating the renal hilum, separating the perinephric region and kidney removal time also increased correspondingly, and the differences among different groups were statistically significant ($P < 0.001$) (Table 2). Therefore, separating the renal hilum is considered to be the rate-limiting procedure for hand-assisted laparoscopic living donor nephrectomy.

Table 1 Differences in postoperative complications among donors with different surgical difficulty scores

Term	Surgical difficulty score			P value		
	1 (n = 31)	2 (n = 23)	3 (n = 6)	1 vs. 2	1 vs. 3	2 vs. 3
Clavien-Dindo classification of donors				0.008	0.01	0.633[a]
I	30	16	3			
II	1	7	3			
Drainage time (days, x ± s)	6.20 ± 1.35	8.22 ± 1.52	11.69 ± 4.17	<0.001	<0.001	<0.001[a]
Hospitalization time (days, x ± s)	12.20 ± 3.09	12.72 ± 4.31	13.62 ± 5.08	1.000	0.279	1.000[a]
DGF (N, %)	6 (19.4%)	3 (13.0%)	2 (33.3%)	0.717	0.591	0.269[a]
Clavien-Dindo classification of recipients						
I	23	15	4	0.475	0.653	1.000[b]
II	8	8	2			
VAS of donor				0.535	0.311	0.617[b]
I	3	1	0			
II	25	21	6			
III	3	1	0			

[a]Multivariate Analysis of Variance (MANOVA), [b]Multiple Chi-Square Test

Table 2 The difference of time for each step of hand-assisted laparoscopic living donor nephrectomy in different surgical difficulty rating groups

Time (min)	Surgical difficulty score			P value		
	1 (n = 31)	2 (n = 23)	3 (n = 6)	1 vs. 2	1 vs. 3	2 vs. 3
Overall operation	96.05 ± 11.73	123.13 ± 6.32	156.41 ± 21.79	<0.001	<0.001	<0.001
Placing the Trocar	6.61 ± 1.15	6.91 ± 1.17	6.83 ± 1.26	0.684	1.000	0.787
Separating the renal hilum	15.72 ± 1.57	20.97 ± 2.25	27.76 ± 3.78	<0.001	<0.001	<0.001
Separating the perinephric region	9.77 ± 0.99	13.66 ± 1.33	19.10 ± 2.04	<0.001	<0.001	<0.001
Removing the kidney	2.16 ± 0.34	2.97 ± 0.57	3.97 ± 0.65	<0.001	<0.001	<0.001

Analysis of influencing factors of surgical difficulty

In terms of pre-operative imaging characteristics of donors, only sagittal abdominal diameter, visceral fat thickness and BMI were correlated with the difficulty of surgery ($P < 0.05$), while age and previous medical history were not significantly correlated with the difficulty of surgery. In terms of pre-operative imaging characteristics of donors, the larger the graft volume, the greater the width of donor kidney, the thicker perirenal, postrenal and visceral fat, the higher the MAP score, and the higher the degree of renal artery calcification, the greater the difficulty of surgery ($P < 0.05$) (Table 3). At the same time, the difficulty of the operation in patients with multiple arteries is also significantly higher than that in patients with single arteries ($P < 0.001$). The mean sagittal abdominal diameter was 19.17 ± 2.42 cm, 20.00 ± 2.88 cm and 20.37 ± 3.32 cm in different surgical difficulty groups, respectively. With the increase of the sagittal abdominal diameter, the surgical difficulty was also increased (Table 4).

In terms of demographic characteristics of donors, only BMI was correlated with the difficulty of surgery ($P < 0.05$), while age, gender and previous diabetes and high blood pressure history were not significantly correlated with the difficulty of surgery.

Establishment and verification of prediction model

With the surgical difficulty score as the dependent variable and the above statistically significant related factors as the independent variables, the linear regression equation was constructed. The results showed that only the number of renal arteries, MAP score and visceral fat thickness were independent risk factors with high surgical difficulty, and the prediction model was as follows: surgical difficulty score = 0.584*Number of renal arteries + 0.731*MAP score + 0.110*visceral fat thickness (Table 5).

Then the model was verified internally and externally to confirm its accuracy. A total of 60 patients in the modeling group in this study were selected by the random number table method for internal verification. The actual values of renal artery number, donor MAP score and visceral fat thickness were respectively brought into the prediction model. The median value of predicted surgical difficulty was 2 (1, 3) points, which was similar to the actual statistical value of 2 (1, 3) points. The paired Wilcoxon test showed no statistical significance ($P > 0.05$). In external verification, a total of 20 patients were selected to perform hand-assisted laparoscopic living donor nephrectomy performed by another surgeon. The actual values of the above influencing factors before surgery were calculated and brought into the prediction model, and the median of the predicted surgical difficulty

Table 3 The correlation between pre-operative imaging characteristics from donor and the surgical difficulty in hand-assisted laparoscopic living donor nephrectomy

Term	Surgical difficulty score			Correlation coefficient	*P* value
	1 ($n=31$)	2 ($n=23$)	3 ($n=6$)		
Graft volume (cm^3, x ± s)	144.19 ± 30.58	158.78 ± 37.68	163.93 ± 34.66	0.248	0.003[a]
Length (cm, x ± s)	10.49 ± 0.89	10.63 ± 1.06	10.60 ± 1.06	0.055	0.521
Width (cm, x ± s)	5.04 ± 0.61	5.33 ± 0.67	5.40 ± 0.59	0.242	0.004
Thickness (cm, x ± s)	5.19 ± 0.64	5.30 ± 0.62	5.45 ± 0.56	0.162	0.057
Thickness of perirenal fat (cm, x ± s)	1.39 ± 0.65	1.61 ± 0.71	1.74 ± 0.89	0.204	0.016[a]
Thickness of postrenal fat (cm, x ± s)	0.67 ± 0.48	0.89 ± 0.44	0.90 ± 0.68	0.198	0.019[a]
Number of donor renal arteries* (N, %)				0.558	<0.001[b]
1	31	15	2		
2	0	8	4		
Number of donor renal veins(N, %)				0.116	0.376
1	30(96.8)	23(100)	5(83.3)		
2	1(3.2)	0(0)	1(16.7)		
MAP score*	1.06 ± 0.25	1.56 ± 0.56	2.45 ± 0.63	0.759	<0.001[b]
Calcification of the renal arteries(Agatston score)	0.68 ± 6.08	3.56 ± 11.25	13.29 ± 36.07	0.258	0.002[a]
Visceral fat thickness (cm, x ± s)	4.66 ± 1.43	5.96 ± 2.07	6.09 ± 2.32	0.351	<0.001[a]
Subcutaneous fat thickness (cm, x ± s)	2.06 ± 0.71	2.27 ± 0.60	2.38 ± 0.73	0.183	0.030[a]
Sagittal abdominal diameter (cm, x ± s)	19.17 ± 2.42	20.00 ± 2.88	20.37 ± 3.32	0.207	0.014[a]
The 12th rib – iliac crest (cm, x ± s)	7.95 ± 2.09	8.56 ± 2.37	7.70 ± 1.74	-0.019	0.826[a]
The 12th rib - the 12th rib (cm, x ± s)	19.21 ± 3.57	19.63 ± 3.57	19.86 ± 3.50	0.088	0.300[a]
Transverse pelvic diameter (cm, x ± s)	25.73 ± 1.37	25.69 ± 1.64	25.80 ± 1.68	0.012	0.888[a]

[a] Pearson correlation test, [b] Spearman correlation test

was 2 (1, 3) points, which was also not statistically significant compared with the actual value of 2 (1, 3) points ($P>0.05$) (Table 6).

Discussion

It is necessary to minimize the warm ischemia time of the kidney while avoiding damage to the kidney and its blood vessels, which makes the operation relatively difficult and the learning curve longer. Previous studies have shown that there was a significant decrease in operating time, blood loss, warm ischemic time and length of stay in patients who underwent laparoscopic donor nephrectomy by an experienced laparoscopist. [16, 17] Zhu et al.'s study of the learning curve for retroperitoneoscopic living-donor nephrectomy (RPLDN) [18] showed that the surgeon completed the initial learning phase of RPLDN after 32 cases and could effectively perform RPLDN after 70 cases. In our study, all HALDN were performed by the same experienced surgeon. However, young doctors may not properly deal with heavy adhesion, saponification of perirenal fat and calcification of blood vessels during the operation, which may lead to complications such as injury of the transplanted kidney and bleeding in the operative area. Therefore, how to complete the operation with high quality and reduce the incidence and severity of postoperative complications on the basis of training young doctors is an urgent problem to be solved.

In our opinion, Experienced surgeons are better able to handle complex anatomies and, in most cases, better than inexperienced surgeons. But this does not mean that these experienced physicians think that some surgeries with anatomical variations, fatty adhesions or other unexpected conditions are easy. Similar to inexperienced physicians, these experienced physicians also find these procedures difficult, but because of their accumulated experience, they can deal with these problems faster and better, reducing the severity and incidence of postoperative complications. Like the surgeon in our clinical center, he also has many years of experience in living donor nephrectomy, but he still classifies it into different grades according to the difficulty of the operation. We believe that this classification of surgical difficulty should apply to all surgeons. The predictive equation for surgical difficulty in our article will help in selecting suitable operators, aiding in the training of young doctors while ensuring safe and efficient completion of surgeries.

In this paper, Clavien-Dindo grading was used to evaluate the severity of postoperative complications. The results showed that the incidence and severity of postoperative complications increased with the increase of surgical difficulty. This also confirms that there is a close

Table 4 The correlation between demographic characteristics of donors and the surgical difficulty in hand-assisted laparoscopic living donor nephrectomy

Term	Surgical difficulty score			Correlation coefficient	*P* value
	1 (*n*=31)	2 (*n*=23)	3 (*n*=6)		
Age (years, x±s)	53.14±6.97	51.09±8.93	52.66±8.92	-0.048	0.572[a]
Male (N, %)*	22 (71.0%)	12(52.2%)	4 (66.7%)	-0.136	0.301[b]
BMI (kg/m^2, x±s)	24.05±2.70	24.78±2.66	25.33±3.84	0.175	0.039[a]
Smoked (N, %)*	5 (16.1%)	0	1 (16.7%)	-0.163	0.214[b]
DM (N, %)*	1 (3.2%)	1 (4.3%)	1 (16.7%)	0.123	0.349[b]
HBP (N, %)*	4 (12.9%)	4 (17.4%)	1 (16.7%)	0.057	0.665[b]
The side of the surgery(N, %)	31(100%)	23(100%)	6(100%)		
History of abdominal surgery(N, %)	1(3.2%)	0	0	-0.114	0.385
ASA score (N, %)*				0.146	0.267[b]
1	2 (6.5%)	1 (4.3%)	2 (33.3%)		
2	29 (93.5%)	22 (95.7%)	4 (66.7%)		
Cholesterol (mmol/L, x±s)	4.43±0.89	4.53±0.79	4.53±1.01	0.049	0.571[a]
Triglyceride (mmol/L, x±s)	1.47±0.87	1.58±0.81	1.73±1.20	0.107	0.217[a]

[a] Pearson correlation test, [b] Spearman correlation test

Table 6 Internal and external validation of surgical difficulty prediction model

Term	Median (P25, P75)		Wilcoxon test	
	Subjective surgical difficulty	Predicted surgical difficulty	Z	P value
Internal validation	2 (1, 3)	2 (1, 3)	-1.000	0.317
External validation	2 (1, 3)	2 (1, 3)	-0.447	0.655

relationship between the difficulty of surgery and postoperative complications. Therefore, it is very necessary to accurately predict the difficulty of surgery before surgery, which can help the clinic choose the appropriate experienced surgeon according to the difficulty of surgery, and minimize the occurrence of postoperative complications.

The results of this study suggest that free renal hilus is the longest and most difficult step in laparoscopic hand-assisted kidney donor extraction. The separation of renal artery is the most important step in the process of free renal portal, and the separation and ligation of multi-branch renal artery will greatly increase the difficulty of operation compared with the single artery donor [19]. Takagi et al. [10] analyzed the data of 1741 living kidney transplant donors, and the results showed that the operation time of multi-branch renal artery donors was significantly longer than that of patients with single-branch renal artery. Our study also found that surgical difficulty was positively correlated with the number of renal arteries. The presence of multiple arteries in the donor kidney will increase the difficulty of separation, ligation, dissociation and other operations, and the time will also be prolonged accordingly, which greatly increases the probability of donor kidney injury and prolonged warm ischemia time.

Our study also found that as the BMI of the donor increased, the difficulty of the operation to obtain the donor kidney also increased. Hagiwara et al. explored the

Table 5 Linear regression analysis of factors related to surgical difficulty

	Nonnormalized coefficient		Normalized coefficient	t	*P* value
	B	Standard Error	Beta		
Constant	-0.254	0.524		-0.485	0.628
Graft volume	0.001	0.002	0.046	0.668	0.506
Width of graft	-0.036	0.093	-0.029	-0.385	0.701
Thickness of perirenal fat	0.099	0.072	0.090	1.368	0.174
Thickness of postrenal fat	-0.066	0.108	-0.043	-0.604	0.547
Number of donor renal arteries	0.584	0.099	0.294	5.903	<0.001
MAP score	0.731	0.060	0.625	12.108	<0.001
Calcification of the renal arteries(Agatston score)	0.003	0.002	0.061	1.235	0.219
ASA score	-0.048	0.105	-0.021	-0.455	0.650
Visceral fat thickness	0.110	0.030	0.263	3.655	<0.001
Subcutaneous fat thickness	0.013	0.059	0.011	0.211	0.833
BMI	0.008	0.014	0.030	0.555	0.580
Sagittal abdominal diameter	-0.034	0.022	-0.120	-1.541	0.126

influence of BMI on the surgical difficulty of laparoscopic radical nephrectomy [20]. The study found that patients with higher BMIs had longer surgeries. This is consistent with our findings. But a multivariate analysis of the study showed that high visceral fat rate was an independent risk factor for prolonged surgery, while body mass index was not. Therefore, Hagiwara et al. suggest that visceral obesity may have a greater impact on the timing and difficulty of laparoscopic surgery than BMI. In our study, BMI and visceral fat thickness were both positively associated with surgical difficulty, but only visceral fat thickness was an independent risk factor for surgical difficulty. MAP score is a scoring system used to evaluate the degree of fat adhesion around the kidney based on preoperative kidney images [13], which can more accurately reflect the fat situation in the operative area of patients compared with BMI. Previous studies have shown that compared with kidney donors with MAP score of 0, kidney donors with MAP score greater than 0 are significantly more difficult to operate [21]. This study also came to the same conclusion: the higher the MAP score, the more difficult the surgery. The author believes that MAP score can reflect the degree of adhesion of perirenal fat more effectively. The higher the MAP score, the more difficult it is to free the kidney and separate the important blood vessels and anatomical structures around the kidney during the operation, which is also an important reason for the increased difficulty of the operation.

The limitations of this study are as follows: First, the data in this study are only from a single center, the sample size is small, and there may be selection bias; Secondly, the definition of surgical difficulty in this paper is relatively subjective, and only a single surgeon with rich experience is used to score the difficulty of surgery, and then a prediction model is obtained. The generality of this model needs to be verified by multi-center surgeons in the future.

Conclusion

With the increase of the difficulty of operation, the incidence and severity of postoperative complications of kidney transplant donors increased correspondingly, and the time of postoperative indentation of drainage tube was also extended correspondingly. We believe that the number of renal arteries, MAP score and visceral fat thickness are independent risk factors for the difficulty of hand-assisted laparoscopic living donor nephrectomy. Meanwhile, this study also developed an effective preoperative evaluation model to predict the difficulty of surgery, which can be used to assist clinical selection of surgeons.

Abbreviations

CT	Computed tomography
HALDN	Hand-assisted laparoscopic living donor nephrectomy
BMI	Body mass index
VAS	Pain visual analogue scale
ASA	American society of anesthesiologists physical status classification
MAP score	Mayo adhesive probability score
SF	Subcutaneous fat thickness
SAD	Sagittal abdominal diameter
RPLDN	Retroperitoneoscopic living-donor nephrectomy

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Author contributions
R.Y. collected and analyze the data, interpreted the results and completed the manuscript. J.L. conceptualized research and revised the manuscript. Z.W. and Y.Z. revised the manuscript. All authors reviewed the manuscript.

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Data availability
The data that support the findings of this study are available from Beijing Friendship Hospital but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Beijing Friendship Hospital.

Declarations

Ethics approval and consent to participate
This study complies with the Declaration of Helsinki and is approved by the Ethics Committee of Beijing Friendship Hospital. All subjects have signed informed consent, and the batch number is: BFHHZS20240073.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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