The learning curve for pure retroperitoneoscopic donor nephrectomy by using cumulative sum analysis

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ABSTRACT

Introduction: This study aimed to identify a precise learning curve for pure retroperitoneoscopic donor nephrectomy (RDN).
Methods: Data from 172 consecutive kidney donors who underwent pure RDN between January 2010 and July 2019 were prospectively collected and evaluated. CUSUM (cumulative sum) analysis was used for testing the operation time. Changepoints were determined by using the r program and Binseg method. The cohort was divided into three groups — group 1: competence, including the first 10 cases; group 2: 11–48 cases as proficiency; and group 3: the subsequent 124 cases as expert level. Continuous variables were evaluated using one-way ANOVA, and categorical data were evaluated using the Chi-squared test.
Results: Right RDN was performed in 39 (22.7%) donors. The eighth patient was converted to open surgery due to vena cava injury and excluded from the CUSUM analysis. Depending on experience in pure RDN, a significant decrease was detected in operative time ($p<0.001$), warm ischemia time ($p=0.006$), and blood loss ($p<0.001$). Recipient complications and graft function were found to be statistically comparable.
Conclusions: In our study, the attainment of expertise in pure RDN was observed after performing 50 cases. The transperitoneal technique, which is a feasible alternative, is far more widely used than pure RDN. We believe that understanding the learning curve associated with pure RDN could facilitate the adoption of this approach as a viable alternative to the transperitoneal approach.

INTRODUCTION

As a standard of care, the significant advantages of minimally invasive laparoscopic living-donor nephrectomy (lldn) are that it decreases postoperative morbidity and improves the quality of life. Various modified techniques, which can be performed by either transperitoneal or retroperitoneal route, have been described over the course of time in line with technological evolution advances and surgical experience[1].

Despite the variety of minimally invasive techniques available, the most preferred approach for donor nephrectomy around the globe is the pure or hand-assisted transperitoneal laparoscopic approach [2]. However, retroperitoneoscopic donor nephrectomy (rdn) allows reaching the renal hilum directly without interference with the intraperitoneal organs. Although it is known as a challenging procedure due to the limited space of the retroperitoneum, operation time is significantly shorter than transperitoneal routes[3]. Both pure and hand-assisted retroperitoneoscopic donor nephrectomy is used at a rate of about 4% around the globe[2].

Since laparoscopic live donor nephrectomy is a challenging and technically demanding procedure, it is important to standardize and disseminate the technique in terms of the education of the next generation of surgeons who want to have experience in the field of laparoscopic donor nephrectomy. However, there are shortcomings in the quantitative definition of the learning curve of rdn. The definitions in the literature have been made only according to the expert opinion in a haphazard manner[4].

In this study, we aimed to determine a meticulous learning curve of pure rdn by using the cumulative sum (cusum) analysis.

METHODS

The prospectively collected data of 172 consecutive kidney donors undergoing pure rdn for transplantation at ondokuz mayıs university from january 2010 to july 2019 were evaluated retrospectively.

Tc-99m mercaptoacetyltriglycine (mag3) renal scintigraphy was performed to evaluate for split renal function. Three-dimensional computed tomography was performed to evaluate kidney anatomy and vasculature. The final decision for the laterality of surgery was based on the conviction that the better kidney remains with the donor. If both kidneys have equal functional characteristics, the left kidney or the kidney with simpler vascular anatomy was procured based on the transplantation medical review board's decision.

The demographic data including age, gender, body mass index (bmi), preoperative renal function, and the number of renal arteries and veins were recorded. Perioperative variables such as operation time (ot), warm ischemia time (wit), estimated blood loss (ebl), and perioperative and postoperative complications were also recorded. Furthermore, the outcomes of renal recipients including graft function, complications, and follow-up were recorded as well.

Our previously published article provides a thorough description of the surgical procedure and details for the right and left sides of pure rdn. All rnds were performed by a

single surgeon with experience in retroperitoneoscopic laparoscopic surgery and kidney transplantation[5].

Learning curve analysis

The cusum analysis and binseg (binary segmentation) method
Although the cusum analysis was first built to evaluate industrial sector performance, its main use in medicine is to calculate many surgical techniques' learning curves. In a timeline, it calculates the sum of the existing differences between individual operation times and the mean of all operation times[6,7]. Its main use in medicine is that calculates the sum of the existing differences between individual operation times and the mean of all operation times in a timeline[8,9]. The next step is to identify significant change points to determine the development. The "changepoint" package was used in the r program to determine the change points. The changepoints were determined according to the mean variation. Binseg methods were used to identify two exchange points. Penalty methods were not used to determine surgical time change points. The "normal" method was used as the test statistic for the surgical time[10].

According to the learning curve analysis methods that are mentioned above, the whole cohort was divided into three groups. Inspired by the dreyfus model of skill acquisition in the naming of the groups. Thus, group 1 represents competence, group 2 is proficiency level, and group 3 is the expert level[11].

Statistical analysis
Data were analyzed using statistics package for social sciences version 24 (ibm spss®, armonk, ny). Conformity to normal distribution was evaluated with the kolmogorov-smirnov test. The chi-square test was used to compare categorical variables according to groups. In the comparison of all groups, one-way analysis of variance (anova) was used for normally distributed data, and the kruskal-wallis test was used for data not normally distributed. The friedman test was used for three or more variables that were not normally distributed, and the wilcoxon sign-rank test was used for two variables in the analysis of the changes in intragroup parameters over time. Analysis outcomes mean ± sd for quantitative data. Were presented as deviation and median (minimum-maximum), and frequency (percent) for categorical data. The significance level was taken as $p<0.05$.

RESULTS
The demographic data of 172 consecutive kidney donors undergoing rdn are shown in table 1. The preoperative variables including age, gender, bmi, and site of the surgery were comparable among groups. Right rdn has been performed in 39 (22.7%) donors. In adherence to the chronological sequence, the eighth kidney donor, presenting with bilateral renal veins on the right side, necessitated a switch to open surgery owing to inadvertent injury to the main renal vein and vena cava during dissection. This case was omitted from the analysis. Nevertheless, the graft was successfully transplanted to the recipient without any complications, although the donor required a postoperative blood transfusion. Figure 1 shows

the number of subjects in the groups having applied the binding method to detect statistical threshold points according to the ot. Figure 2 shows the plot of cusum of ot against the case number from the very first to the last. Group 1, group 2, and group 3 involved 10, 38, and 124 donors respectively. Table 2 shows intraoperative variables. There have been statistically significant decreases in ot, wit, and ebl detected when the three groups were compared. After 48 rdn, in which the proficiency level was achieved, the mean ot time was 69,6 min, wit was 135,3 seconds, and the median ebl was about 100 ml.

Overall postoperative complications were minor ones according to the clavien-dindo classification. No major complications were encountered, postoperatively. All donors were discharged seamlessly as well.

The three groups were comparable in terms of complications in the recipients including venous thrombosis and graft nephrectomy rate. Moreover, the functional outcomes of the recipients were also comparable in the second year, postoperatively.

DISCUSSION

The present study has revealed that a single surgeon should perform about 50 cases to achieve an expert level in pure rdn. However, it is a lack of importance that there is no standard and trustworthy curriculum providing the necessary education and skill acquisition for rdn worldwide. We may speculate that it is crucial to determine the number of cases that should be performed in transplantation fellowship programs in centers in which rdn is routinely performed for kidney harvesting.

Given the technical properties of the rdn approaches, reaching the renal hilum directly in the early stage of surgery is advantageous for vascular control. A recent meta-analysis claimed that hem-o-lok clips and staplers have similar safety and complication rates, we have been using endo-ta-30 stapler (covidien, mansfield, ma) for both renal artery and vein control from the first case[12]. We genuinely think that using an endo ta stapler allows us to obtain an adequate length of the renal vein, particularly on the right side. With the application of an endo ta stapler at the level of the intersection of the renal vein and inferior vena cava can acquire a sufficient renal vein length on the right side as well. Therefore, our cohort's right-sided rdn rate includes of 22.7% (39 cases), comparable to recent literature[13,14].

Statistically significant changes in ot on the learning curve analysis that used the cusum method are the main basis of the studies. However, there is no convincing data for pure rdns in the literature. In the initial study conducted by pat et al., it was found that operative time (ot) and warm ischemia time (wit) exhibited significant reductions upon reaching a level of expertise. However, in this particular study, despite completing the learning curve, the ot remained for approximately 200 minutes[15]. On the contrary, a recent systematic review and meta-analysis which evaluates both retroperitoneoscopic and transperitoneal laparoscopic donor nephrectomies state that the ot was significantly shorter by 77 minutes in pure rdns compared to transperitoneal counterparts[14]. Within our study, the average operative time (ot) was 75 minutes, which subsequently decreased to approximately 70 minutes upon attaining the level of expertise.

It is crucial to avoid making the assumption that a shorter operative time (ot) is not a significant factor in laparoscopic donor nephrectomies. The literature lacks clarity regarding the impact of pneumoperitoneum on both the donor's remaining kidney and graft function[16]. However, we believe that with a shorter ot and wit, it will be better to prevent both the donor's remnant kidney and the graft kidney from acute injury due to pneumoperitoneum in terms of functional outcomes.

The limitations of our study include retrospective, single-center, and single-surgeon experience. The outcomes indicate single surgeon experience which might make it difficult to generalize. Moreover, it should be stated that having experience in retroperitoneoscopic upper urinary tract surgeries including radical nephrectomy, partial nephrectomy, and pyeloplasty may facilitate the learning curve of rdn. The implementation of the retroperitoneoscopic donor nephrectomy (rdn) technique in our clinic occurred at a later stage compared to other retroperitoneoscopic kidney surgeries previously mentioned.

The effects of mentor-led training on the learning curve of future generations of surgeons have not been evaluated. Nevertheless, as our expertise in this domain continues to expand, we anticipate being able to provide more comprehensive and informative insights in the forthcoming years. In this study, a more qualitative assessment method was utilized to evaluate the learning curve of rdn, distinguishing it from previous studies. We believe that this research might contribute to the increased adoption of the retroperitoneoscopic technique.

CONCLUSIONS

In our study, the attainment of expertise in pure rdn was observed after performing 50 cases. However, this learning process could potentially be accelerated through participation in a fellowship program under the guidance of a mentor, as well as through the utilization of auxiliary methods such as video simulation and dry lab practices. Our belief is that the training of future generations in retroperitoneoscopic donor nephrectomy using standardized methods will gain more popularity.

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FIGURES AND TABLES

Figure 1. Changepoints were determined by using the binseg method.

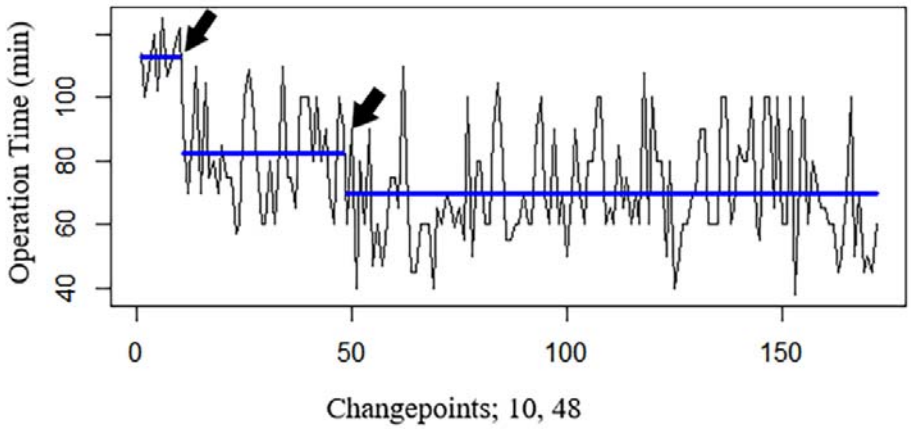

Figure 2. The plot of cumulative sum analysis (CUSUM) of operation time against the case number.

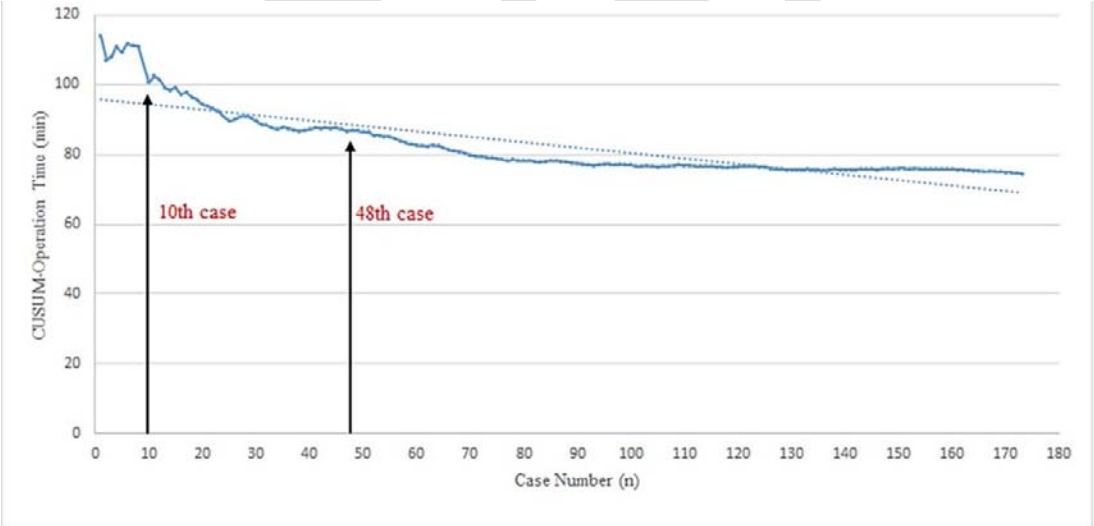

Table 1. Demographic features of the groups						
Variables	**Group 1**	**Group 2**	**Group 3**	**Total**	**Test statistic**	**p**
Number, n (range)	10 (1–10)	38 (11–48)	124 (49–172)	172		
Age, year	44.4±8.3	41.9±9.8	43.9±11.4	43.5±10.9	F=0.526	0.592
BMI, kg/m^2	26.4±1.7	26.6±4	26.9±3.9	26.8±3.8	F=0.186	0.831
Sex, n (%)						
Male	6 (60)	17 (44.7)	50 (40.3)	73 (42.4)	X^2=1.572	0.456
Female	4 (40)	21 (55.3)	74 (59.7)	99 (57.6)		
Site, n (%)						
Left	7 (70)	30 (78.9)	96 (77.4)	133 (77.3)	X^2=0.364	0.834
Right	3 (30)	8 (21.1)	28 (22.6)	39 (22.7)		
Multiple arteries	1	1	2	4		
Preoperative renal function						
Cr (mg/dl)	0.7±0.2	0.8±0.2	0.8±0.8	0.8±0.6	F=0.290	0.749
eGFR (CKD-EPI)	105.8±6.6	108.9±8.3	104.9±14.9	105.8±13.4	5495*	0.064

*Kruskal-Wallis test statistic; χ2: Chi-squared test statistic; F: analysis of variance test statistic. BMI: body as index; CKD: chronic kidney disease; Cr: creatinine; eGFR: estimated glomerular filtration rate (in ml/min/1.73 m²); EPI: exocrine pancreatic insufficiency.

Table 2. Perioperative and postoperative outcomes						
	Group 1	**Group 2**	**Group 3**	**Total**	**Test statistic**	**p**
Operation time, min	112.7±8.4[a]	82.4±16.1[b]	69.6±17.5[c]	75±19.9	F=35.22	<0.001
Warm ischemia time, sec	176.6±49.4[b]	140.2±58.7[a]	135.3±72.6[a]	138.8±69	10.212[*]	0.006
Estimated blood loss, ml	167±25.9[a]	132.6±20.4[a]	95.7±27.6[b]	108±33.5	67.617[*]	<0.001
Postoperative complication, n (%)						
No	10 (100)	35 (92.1)	123 (99.2)	168 (97.7)	X^2=6.686	0.035
Minor	0 (0)	3 (7.9)	1 (0.8)	4 (2.3)		
Venous thrombosis, n (%)	0 (0)	1 (2.6)	1 (0.8)	2 (1.2)		
Graft rejection, n (%)						
No	8 (80)	32 (84.2)	106 (85.5)	146 (84.9)	X^2=0.234	0.89
Yes	2 (20)	6 (15,8)	18 (14,5)	26 (15,1)		
Graft nephrectomy, n (%)						
No	9 (90)	36 (94.7)	123 (99.2)	168 (97.7)	X^2=5.296	0.071
Yes	1 (10)	2 (5.3)	1 (0.8)	4 (2.3)		
Recipient gender, n (%)						
Male	8 (80)	16 (42.1)	75 (60.5)	99 (57.6)	X^2=6.211	0.051
Female	2 (20)	22 (57.9)	49 (39.5)	73 (42.4)		
Recepient creatinine, mg/dl						
6 months	1 (0.5–1.5)[a]	1 (0.5–2.4)[ab]	1.1 (0.5–5.4)[a]		4.32[**]	0.115
2 years	1.2 (0.5–2.4)[a]	1 (0.5–2.7)[ab]	1.2 (0.6–2.5)[a]		5.834[**]	0.054
3 years	1.3 (0.5–2.7)[a]	1 (0.6–2.7)[ab]	1.1 (0.5–4.1)[a]		3.621[**]	0.164
Followup, months	102.1±1.6[a]	81.9±8.5[b]	24.3±17.8[c]	41.6±32.2	F=273.49	<0.001

[*]Kruskal-Wallis test statistic; **Friedman test statistic. F: analysis of variance test statistic; χ2: Chi-squared test statistic.