# 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. Cumulative sum (CUSUM) 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 RDN is used at a rate of about 4% globally.[2]

Since LLDN 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 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 assess 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 remain with the donor. If both kidneys had 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 operative 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 followup, 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 RDNs were performed by a single surgeon with experience in retroperitoneoscopic laparoscopic surgery and kidney transplantation.[5]

**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/m² | 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) | $\chi^2$=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) | $\chi^2$=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; $\chi^2$: 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.

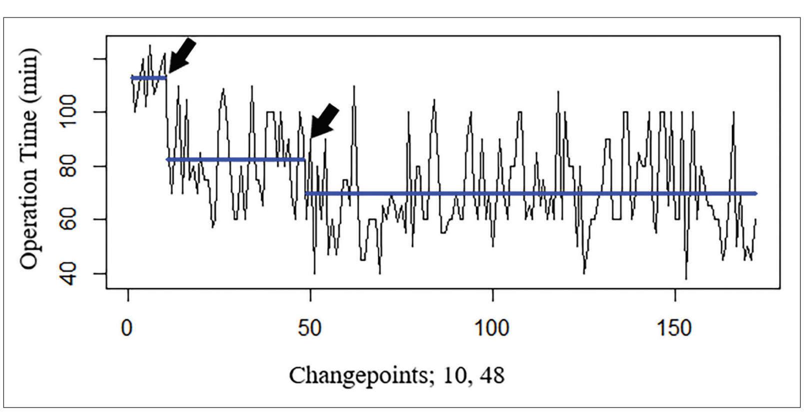


**Figure 1.** Changepoints were determined by using the BINSEG method.

### Learning curve analysis

Although the CUSUM analysis was first built to evaluate industrial sector performance, its main use in medicine is to calculate the sum of the existing differences between individual OTs and the mean of all operation times in a timeline.[6-9] The next step is to identify significant changepoints to determine the development. The "changepoint" package was used in the r program to determine the changepoints according to the mean variation. The BINSEG method was used to identify two exchange points. Penalty methods were not used to determine surgical time changepoints. The "normal" method was used as the test statistic for the surgical time.[10]

According to the learning curve analysis methods mentioned above, the full cohort was divided into three groups: group 1 represents competence; group 2 is proficiency level; and group 3 is expert level.[11]

### Statistical analysis

Data were analyzed using statistics package for social sciences version 24 (IBM SPSS®, Armonk, NY, U.S.). Conformity to normal distribution was evaluated with the Kolmogorov-Smirnov test. The Chi-squared 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 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 intra-group parameters over time. Analysis outcomes are listed as mean ± standard deviation for quantitative data. Categorical data are presented as deviation and median (minimum-maximum) and frequency (percent). The significance level was set at $p<0.05$.

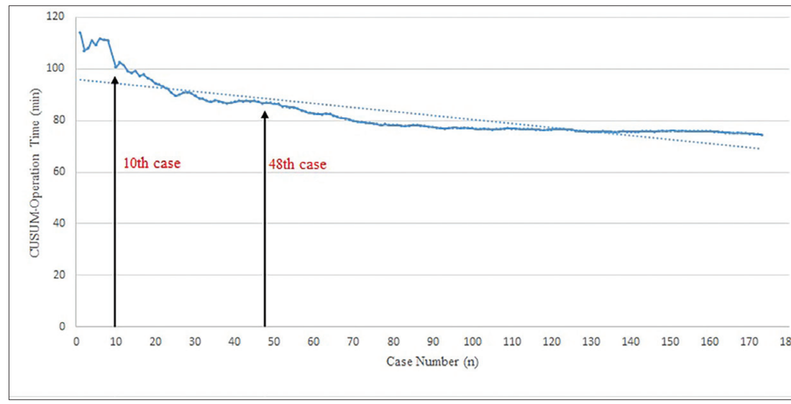


**Figure 2.** The plot of cumulative sum analysis (CUSUM) of operation time against the case number.

**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) | $\chi^2$=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) | $\chi^2$=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) | $\chi^2$=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) | $\chi^2$=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. [a,b,c] Different lowercase letters show a significant difference between groups by one-way ANOVA. F: analysis of variance test statistic; $\chi^2$: Chi-squared test statistic.

## 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 was 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 into 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 first to the last. Groups 1, 2, group 3 involved 10, 38, and 124 donors, respectively. Table 2 shows intraoperative variables. There were statistically significant decreases in OT, WIT, and EBL detected when the three groups were compared. After 48 RDNs, in which the proficiency level was achieved, the mean OT time was 69.6 minutes, WIT was 135.3 secon ds, and the median EBL was about 100 ml.

Overall postoperative complications were minor according to the Clavien-Dindo classification. No major complications were encountered postoperatively. All donors were discharged without incident.

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 reveals that a single surgeon should perform approximately 50 cases to achieve expert level in pure RDN; however, there is no standard curriculum providing the necessary education and skill acquisition for RDN worldwide.

Given the technical properties of the various RND 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, U.S.) for both renal artery and vein control from our very first case,[12] as we believe it allows us to obtain an adequate length of the renal vein, particularly on the right side. As a result, our cohort's right-sided RDN rate is 22.7%, which is comparable to recent literature.[13,14]

While the literature lacks clarity regarding the impact of pneumoperitoneum on both the donor's remaining kidney and graft function,[15] we believe that shorter OT and WIT can prevent acute injury to both the donor's remaining kidney and to the graft kidney.

A study by Pal et al was found that both were significantly reduced upon reaching a level of RDN expertise; however, in this particular study, despite completing the learning curve, the OT remained approximately 200 minutes.[16] In contrast, a recent systematic review and meta-analysis that evaluated both retroperitoneoscopic and transperitoneal laparoscopic donor nephrectomies showed that the OT was significantly shorter by 77 minutes in pure RND compared to transperitoneal procedures.[14] In our study, the average OT was 75 minutes, which subsequently decreased to approximately 70 minutes upon attaining the level of expertise.

### Limitations

In this study, a qualitative assessment method was used 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 for kidney donation. There are some important limitations to address, however, including the retrospective nature of the study. Furthermore, we have only evaluated data from a single center and a single surgeon, making generalizability difficult. Moreover, it should be noted that the implementation of the RDN technique in our clinic occurred at a later stage compared to other retroperitoneoscopic kidney surgeries; having experience in retroperitoneoscopic upper urinary tract surgeries, including radical nephrectomy, partial nephrectomy, and pyeloplasty, could have facilitated the learning curve of RDN.

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 insight in the coming years.

## 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 by auxiliary methods, such as video simulation and dry lab practices. The goal is to train future clinicians in RDN using standardized methods.

COMPETING INTERESTS: The authors do not report any competing personal or financial interests related to this work.

This paper has been peer-reviewed.

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