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How Long Does It Take to Acquire Mastery of Performance in Laparoscopic Living Donor Nephrectomy? A Center-Based and Surgeon-Based Operative Time CUSUM Analysis

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ABSTRACT

Background. The safety of laparoscopic donor nephrectomy (LDN) has been widely documented, but its challenging learning curve (LC) requires an insightful assessment to expand its application. The aim of this study was to evaluate LC of LDN in a high-volume transplant center.

Methods. Three hundred forty-three LDNs performed from 2001 to 2018 were evaluated. CUSUM analysis based on the operative time was used to assess the number of cases required to reach mastery in the technique for both the entire surgical team and for the 3 main surgeons considered separately. Analysis of association between demographics, perioperative characteristics, and complications within the different LC phases was conducted.

Results. Mean operative time was 228.9 minutes. Mean length of stay was 3.8 days and mean warm ischemia time (WIT) was 170.8 seconds. Surgical and medical complication rates were 7.3% and 6.4%, respectively. The CUSUM-LC showed a requirement of 157 cases (for surgical team) and 75 cases (for single surgeons) to reach competence in the procedure. Patient baseline characteristic showed no differences among the LC phases. Compared with the initial LC phase, hospital stay was significantly lower at the end of the LC whereas WIT results were longer in the LC descendent phase.

Conclusions. This study confirms the safety and efficacy of LDN, with a low rate of complications. This analysis suggests that about 75 procedures are required to reach competence and 93 cases to achieve mastery level of skill for a single surgeon. It can be hypothesized that, in a high-volume transplant enter, the time to guarantee training in LDN is compatible with the duration of a clinical fellowship.

LAPAROSCOPIC donor nephrectomy (LDN) is a widely accepted technique for kidney retrieval in living donor kidney transplantation (LDKT). Ratner et al described the first LDN in 1995 [1], and since then LDN has been widely performed at transplant centers in the US and worldwide [2]. According to the 2016 Organ Procurement and Transplantation Network report, the laparoscopic hand-assisted and the pure laparoscopic techniques for donor nephrectomy account for more than 97% of procedures used during LDKT [3].

The advantages offered by the minimally invasive techniques likely contributed to the substantial growth in the rates of LDKT. In fact, the time to recovery, the rate of surgical

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complications, and the postoperative pain and discomfort represent some of the most important outcomes for living kidney donors [4] and they have been more satisfactorily addressed by the laparoscopic approach [5]. In a national US survey including almost 15,000 living kidney donors, laparoscopic technique was applied in 93.8% of the cases, showing a significant advantage in terms of any complication compared with the open technique. Nevertheless, there are some centers reluctant to adopt this surgical approach because of concerns related to its safety and its long learning curve (LC). For example, Ravaioli et al showed in a multicenter Italian study that only 78% of the LDN were performed laparoscopically, of which 60% used a fully laparoscopic approach [6].

Notably, the safety concerns might be related to inadequate laparoscopic skills of some categories of transplant surgeons. Even for urologists trained in mini-invasive techniques, LDN represents a challenging operation: in 2001 Guillonneau et al rated LDN as the third most difficult laparoscopic urological procedure, using a scoring system that considered technical difficulty, risks, and attention required during the operation [7]. The volume of experience needed to safely perform the procedure is considerable, with a relatively higher rate of complications at the beginning of the LC [8−11].

The aim of the present study was to evaluate the LC of LDN in a transplant unit that progressively became a high-volume center (from <10 LDN/year in 2001 to 58 LDN/year in 2017) to determine the number of procedures required to achieve an elevated level of proficiency. Because both the rate of perioperative complications and the blood losses/need for transfusions were extremely low, only operative time was used as proficiency index for LDN.

MATERIALS AND METHODS

A retrospective review of 349 LDNs performed at the Kidney and Pancreas Transplantation Unit of Padua University Hospital between November 2001 and February 2018 was carried out. Patients who had a synchronous operation (2 adrenalectomy, 3 cholecystectomy, 1 adrenal nodule excision) were excluded to reduce confounding factors that can affect outcomes and operative times. Therefore, 343 LDNs were evaluated in the study, performed by 3 different surgeons. The first surgeon performed 30 cases from November 2001 to July 2007; the second performed 68 cases from August 2007 to August 2017; and the third performed 245 LDNs from January 2010 to February 2018.

A fully laparoscopic approach was used for left LDN whereas a modified hand-assisted technique was used in case of right nephrectomy. After completing the vascular dissection, the first operator's left hand is inserted in the abdomen through the Pfannenstiel incision to complete the dissection of the right kidney from the fat tissue and, more importantly, to gently retract the right kidney to place the stapler as closer as possible to the cava vein and to achieve a longer renal vein [12].

For the analysis of patients' baseline characteristics, the following variables were considered: sex, age, body mass index, prior abdominal surgery, right or left kidney, renal vascular anomalies, risk factors (smoking, hypertension, and hypercholesterolemia) and serum creatinine. The following intraoperative and postoperative outcomes were analyzed: operative time, warm ischemia time (WIT), length of hospitalization, intraoperative complications and postoperative surgical complications categorized by Clavien-Dindo classification, medical complications, and serum creatinine at 3 months postoperatively.

Statistical Analysis

The statistical analysis was performed using the R software (version 3.4.3., The R Project for Statistical Computing). Continuous variables were reported as mean ± standard deviation and were compared using analysis of variance. Categorical variables were reported as absolute numbers of patients and percentage and were compared using χ^2 tests or Fisher's exact test. Post-hoc analysis with Bonferroni correction method was used to compare the learning phases. The level for rejection of the null hypothesis was set at a *P* value <.05. Additionally, a *P* value <.0167 was considered statistically significant after Bonferroni correction for the post-hoc analysis.

The cumulation sum (CUSUM) method, based on operative time, was used to assess the LC of LDN. It was applied initially for the unit's entire surgical team, and consequently for each single surgeon.

RESULTS

Overall patient characteristics are described in detail in Table 1. Postoperative surgical complications and medical complications are reported in Table 2. Only one intraoperative complication occurred (0.29%), which was due to a stapler misfiring and required conversion to laparotomy.

CUSUM Analysis and Operative Times

According to the CUSUM, the surgical team collected 2 peak points, which were observed at the 157th and 179th case (Fig 1). Based on single surgeon's CUSUM graph, there were 2 peak points for each one, founded at the 8th and 11th case for

Table 1. Overall Patient Characteristics

Characteristic	N = 343
Sex, n (%)	
Male	100 (29.2)
Female	243 (70.8)
Age, years, mean ± SD	51 ± 10.2
BMI, kg/m^2, mean ± SD	24.9 ± 3.4
Prior abdominal surgery, n (%)	167 (48.7)
Right kidney, n (%)	56 (16.3)
Arterial vascular anomalies, n (%)	68 (19.8)
Venous vascular anomalies, n (%)	37 (10.8)
Risk factor, n (%)	
Smoking	94 (27.4)
Hypertension	48 (14)
Hypercholesterolemia	15 (4.4)
Operative time, min, mean ± SD	228.9 ± 54.8
Warm ischemia time, sec, mean ± SD	170.8 ± 65.7
Length of hospitalization, days, mean ± SD	3.8 ± 1.2
Surgical intraoperative complications, n (%)	1 (0.3)
Surgical postoperative complications, n (%)	24 (7)
Medical complications, n (%)	22 (6.4)
Basal creatinine, mg/dl, mean ± SD	0.79 ± 0.15
3-months serum creatinine, mg/dl, mean ± SD	1.17 ± 0.23

BMI, body mass index.

Table 2. Postoperative Complications

	N	Clavien-Dindo Classification
Surgical complications:	25	
Chyloperitoneum	5	I
Seroma/hematoma	13	I
Wound dehiscence	1	I
Hydrocele	1	I
Anemization requiring blood transfusion	4	II
Medical complications:	22	—
Respiratory	20	—
Clostridium diarrhea	1	—
Anesthesiological	1	—

the first surgeon (Fig 2), at the 39th and 55th case for the second surgeon (Fig 3), and at 75th and 93rd case for the third surgeon (Fig 4).

In line with these results, the LC for LDN was finally determined and it consisted of 3 phases both for the team and for each single surgeon. The team LC was determined as phase 1 (the initial LC): 157 cases (1-157); phase 2 (the competent period): 22 cases (158-179), and phase 3 (the mastery and challenging period): 164 cases (180-343). In phase 1, 19.1% of LDNs were performed by the first surgeon, 35% by the second surgeon, and the 45.9% by the third surgeon; in phase 2 and 3 LDNs were performed only by the second and third surgeon. In particular, in phase 2, 4.5% of LDNs were performed by the second surgeon and 95.5% by the third surgeon; in phase 3, 7.3% were performed by the second surgeon and 92.7% by the third surgeon.

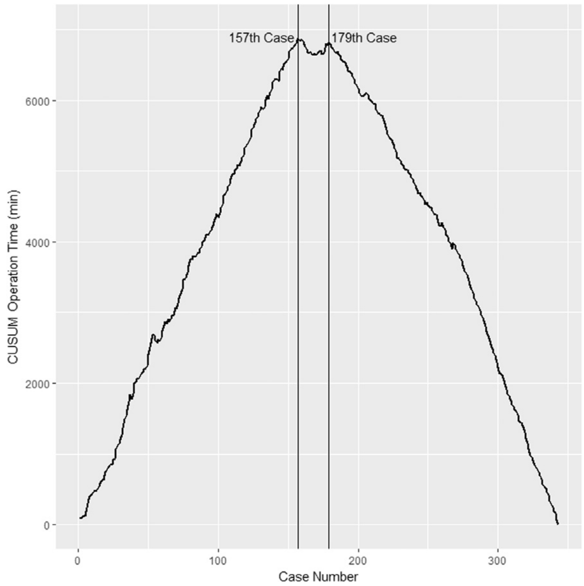

Fig 1. Kidney and Pancreas Transplantation Unit at Padua University Hospital CUSUM Operation Time plotted against case number. The best fit for the curve is a second-order polynomial with equation CUSUM Operation time = −908.67 + 81 x (Case number) −0.23 x (Case number)^2 (R-squared =0.9706)

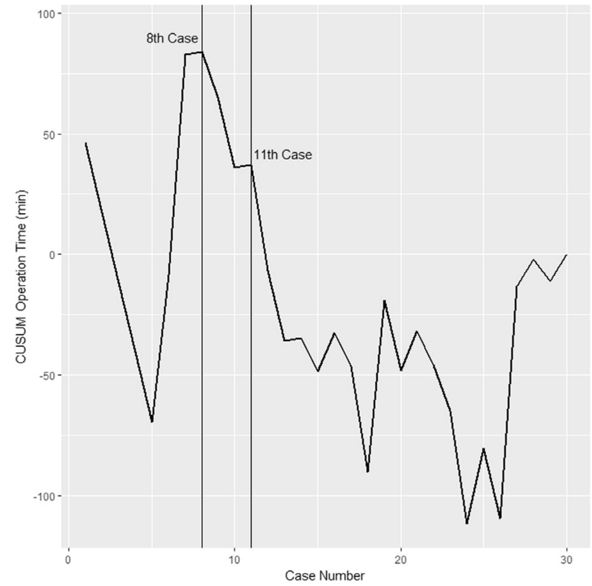

Fig 2. First surgeon CUSUM operation time plotted against case number

As expected, operative time displayed significant differences among all learning phases ($P < .001$). With accumulation of experience, operative time tended to decrease. Table 3 reports mean operative time for each LC phase.

Operative time for the first surgeon did not display significant differences among all learning phases ($P = .594$) or in the interphase comparison ($P = 1$). These results suggested the nonrepresentability of first surgeon's LC, considering the increase of

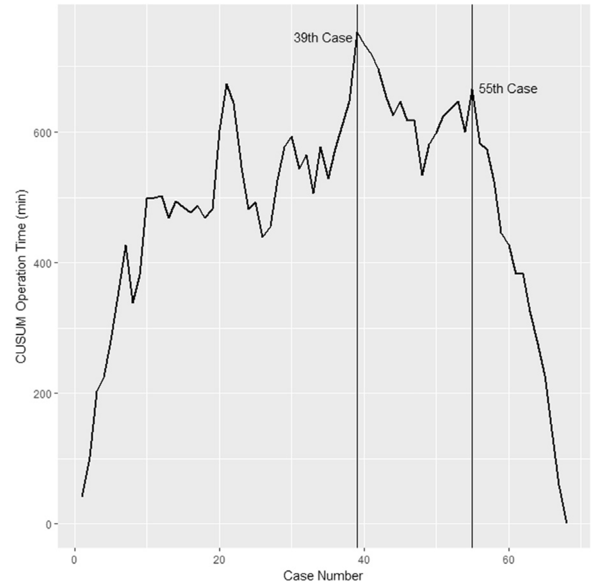

Fig 3. Second surgeon CUSUM operation time plotted against case number

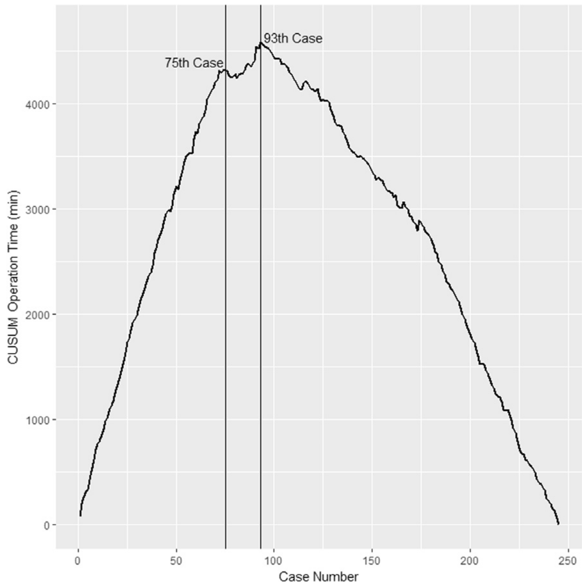

Fig 4. Third surgeon CUSUM operation time plotted against case number

mean operative time in phase 3 compared with phase 2 (phase 2 vs phase 3, 253.33 ± 15.27 vs 266.95 ± 37.66 minutes).

There was significant difference in the operative time of the second surgeon among all learning phases (*P* =9.01e-05). However, in the interphase comparison, the only significant difference was between phase 1 and 3 (phase 1 vs phase 3, 278.24 ± 5.43 vs 207.69 ± 28.48 minutes, [*P* =5.7e-05]), suggesting that in phase 2 and 3 there were minimal changes (stagnant improvement) in terms of operative time reduction compared with phase 1 and 2, respectively.

Table 3 and 4 report the results for the entire surgical team concerning the comparison by learning phase of patients' characteristics and operative outcomes. The same data analysis was carried out for the third surgeon separately (Table 5 and 6), who was the one with the highest number of LDNs performed, and the results reflect mostly those observed for the entire team.

Patient Baseline Characteristics Compared by Learning Phase

According to the comparison between the 3 learning phases, there were no significant differences when looking at patients' baseline characteristics. The removal of right kidney was distributed more in phase 2 than in phase 1 (*P* = .009218) and in phase 3 (*P* = .0433), suggesting there was a tendency to remove the right kidney in the competent period (Table 3).

Intraoperative and Postoperative Outcomes Compared by Learning Phase

There were significant differences regarding WIT between phase 1 and phase 2 and 3. Compared with phase 1, WIT was longer in phase 2 (*P* = .0016) and in phase 3 (*P* = .0109). Compared with phase 1, the length of hospitalization was significantly lower in phase 3 (*P* < .001). The occurrence of complications showed no differences among all learning phases (*P* = .1508). The rate of surgical complications was 4.46% in phase 1, 9.09 % in phase 2, and 9.76 % in phase 3. Although there were no significant differences among the phases, the rate in phase 1 was lower than in phase 2 and 3. There were no significant differences in medical complications among all phases during the learning process (*P* = .7271). Three-month serum creatinine showed no significant difference among the 3 phases (*P* = .0131), as well as in the interphase comparison (Table 4).

DISCUSSION

The laparoscopic approach has increasingly become the gold standard in LDN, although its safe application requires a specific training that includes not only the achievement of technical laparoscopic skills, but also experience with kidney transplantation and a high level of attention to preserve both the kidney and the donor [7]. It would be extremely important to obtain an estimate of the number of procedures needed to permit an adequate training period for a surgeon to perform LDN safely and proficiently.

For this purpose, several authors carried out studies focused on LC for LDN [13−17]. Some groups reported that surgical

Table 3. LDN Intraoperative and Postoperative Outcomes Compared by Learning Phases

Intraoperative and Postoperative Outcomes	Phase 1 (N = 157)	Phase 2 (N = 22)	Phase 3 (N = 164)	*P* value	*P* value 1 vs 2	*P*- value 1 vs 3	*P*- value 2 vs 3
Operative time, min	272.71 ± 42.07	225.91 ± 40.20	187.32 ± 28.29	<.001[*]	<.001[†]	<.001[†]	<.001[†]
Warm ischemia time, sec	159.65 ± 54.07	210.91 ± 100.51	180.74 ± 67.63	<.001[*]	.0016[†]	.0109[†]	.1204[†]
Length of hospitalization, days	4.22 ± 1.17	3.91 ± 1.38	3.46 ± 1.01	<.001[*]	.6466 [†]	<.001[†]	.2226[†]
Surgical complications	7 (4.46)	2 (9.09)	16 (9.76)	.1508[§]	.3051[§]	.08324[§]	1[§]
None	150 (95.54)	20 (90.91)	148 (90.24)				
Medical complications	9 (2.62)	2 (9.09)	11 (6.71)	.7271[§]	.628[§]	.819[§]	.6547[§]
None	148 (97.38)	20 (90,91)	153 (93.29)				
3-month serum creatinine	1.20 ± 0.30	1.05 ± 0.14	1.14 ± 0 .21	.0131[*]	.0300[†]	.1263[†]	.3358[†]

LDN, laparoscopic donor nephrectomy.

* One-way analysis of variances among groups

† Post-hoc analysis with the Bonferroni correction method[‡] χ^2 test test

§ Fisher's exact test

Table 4. LDN Patient Baseline Characteristics Compared by Learning Phases

Patient Characteristics	Phase 1 (n = 157)	Phase 2 (n = 22)	Phase 3 (n = 164)	*P* value	*P* value 1 vs 2	*P*- value 1 vs 3	*P*- value 2 vs 3
Age, y	50.36 ±10.06	48.46 ± 9.63	51.96 ±10.37	0.178*	1†	.4756 †	.3902†
Sex							
Male	50 (31.85%)	5 (22.73%)	45 (27.44%)				
Female	107 (68.15%)	17 (77.27%)	119 (72.56%)	.5421‡	.5342‡	.4577‡	.8321‡
BMI, kg/m^2	25.04 ± 3.46	23.56 ± 3.57	25.10 ± 3.32	.132*	.1704†	1†	.1416†
Right kidney used	20 (12.74%)	8 (36.36%)	28 (17.07%)	.02472§	.009218§	.3477§	.0433§
Left kidney used	137 (84.26%)	14 (63.64%)	136 (82.93%)				
Arterial anomalies	39 (24.84%)	3 (13.64%)	26 (15.85%)	.09961§	.2955§	.05202§	1§
None	118 (75.16%)	19 (86.36%)	138 (84.15%)				
Venous anomalies	17 (10.83%)	3 (13.64%)	17 (10.37%)	.8852§	.7173§	1§	.7116§
None	140 (89.17%)	19 (86.36%)	147 (89.93%)				
Prior abdominal surgery	73 (47.13%)	9 (40.91%)	81 (49.40%)	.5972‡	.7916‡	.5318‡	.5303‡
None	84 (52.87%)	13 (59.09%)	83 (50.60%)				
Risk factor: Smoking	40 (25.48%)	8 (36.63%)	46 (28.05%)	.5448‡	.7916‡	.5318‡	.5303‡
None	117 (74.52%)	14 (63.64%)	118 (71.95%)				
Risk factor: Hypertension	18 (11.47%)	4 (18.18%)	26 (15.85%)	.3814§	.484§	.2615§	.7603§
None	139 (88.53%)	18 (81.82%)	138 (84.15%)				
Risk factor:							
Hypercholesterolemia	8 (5.10%)	1 (4.55%)	6 (3.66%)	.6965§	1§	.5924§	.5921§
None	149 (94.90%)	21 (95.45%)	158 (96.34%)				
Basal serum creatinine	0.79 ± 0.15	0.78 ± 0.12	0.79 ± 0.16	.905*	1†	1†	1†

BMI, body mass index.
* One-way analysis of variances among groups
† Post-hoc analysis with the Bonferroni correction method
‡ χ^2 test test
§ Fisher's exact test

Table 5. LDN Patient Baseline Characteristics Compared by Learning Phases for the Third Surgeon

Patient Characteristics	Phase 1 (n = 75)	Phase 2 (n = 18)	Phase 3 (n = 152)	*P* value	*P* value 1 vs 2	*P*- value 1 vs 3	*P*- value 2 vs 3
Age, y	50.16 ± 9.11	49.39 ± 9.75	51.70 ±10.40	.245*	1†	.8216†	1†
Sex							
Male	20 (26.77%)	4 (22.22%)	42 (27.63%)	.9472§	1§	.9306§	.7824§
Female	55 (73.33%)	14 (77.78%)	110 (72.37%)				
BMI, kg/m^2	24.77 ± 3.49	23.78 ± 4.40	25.62 ± 3.82	.0679*	.9584†	.3275†	.1532†
Right kidney used	17(22.67%)	7 (38.89%)	27(17.76%)	.09995§	.2284§	.3785§	.05578§
Left kidney used	58(77.33%)	11(61.11%)	125(82.24%)				
Arterial anomalies	19 (25.33%)	3(16.67%)	23 (15.13%)	.1637§	.5481§	.07079§	.7414§
None	56 (74.64%)	15(83.33%)	129(84.87%)				
Venous anomalies	7(12.95%)	3 (16.67%)	15 (9.87%)	.5852§	.4007§	1§	.4115§
None	68(87.05%)	15(83.33%)	137(90.13%)				
Prior abdominal surgery	37(49.33%)	7(38.89%)	81 (53.29%)	.4822‡	.5932‡	.6745‡	.3646‡
None	38(50.67%)	11 (61.11%)	71(46.71%)				
Risk factor:							
Smoking	17 (22.67%)	7(38.89%)	40 (26.32%)	.3833§	.2284§	.6268§	.2728§
None	58(77.33%)	11(61.11%)	112(73.68%)				
Risk factor:							
Hypertension	10(13.33%)	4 (22.22%)	25 (16.45%)	.6146§	.461§	.6963§	.515§
None	65(86.67%)	14 (77.78%)	127(83.55%)				
Risk factor:							
Hypercholesterolemia	7 (9.33%)	1 (5.56%)	5 (3.29%)	.1435§	1§	.06542§	.4945§
None	68(90.67%)	17(94.44%)	147(96.71%)				
Basal serum creatinine	0.76 ± 0.15	0.77 ± 0.12	0.79 ± 0.16	.314*	1†	.4171†	1†

BMI, body mass index; LDN, laparoscopic donor nephrectomy.
* One-way analysis of variances among groups
† Post-hoc analysis with the Bonferroni correction method
‡ χ^2 test test
§ Fisher's exact test

Table 6. LDN Intraoperative and Postoperative Outcomes Compared by Learning Phases for the Third Surgeon

Intraoperative and Postoperative Outcomes	Phase 1 (N = 75)	Phase 2 (N = 18)	Phase 3 (N = 152)	*P* value	*P* value 1 vs 2	*P*- value 1 vs 3	*P*- value 2 vs 3
Operative time, min	273.23 ± 36.14	230.28 ± 41.64	185.49 ± 27.60	<2e-16*	1.4e-06†	< 2e-16[b]	1.1e-07[b]
Warm ischemia time, sec	152.32 ± 57.26	226.39 ± 96.45	181.97 ± 77.67	.000248*	.0004†	.01409†	.04871†
Length of hospitalization, days	4.09 ± 1.11	3.56 ± 0.62	3.49 ± 1.03	.000197*	.14343†	.00013†	1†
Surgical complications	3(4%)	1 (5.56%)	16(10.53%)	.2242§	1§	.1268§	1§
None	72 (96%)	17(94.44%)	136 (89.47%)				
Medical complications	7 (9.33%)	1 (5.56%)	10 (6.58%)	.7221§	1§	.4374§	1§
None	68 (90.67%)	17 (94.44%)	142 (93.42%)				
3-month serum creatinine	1.22 ± 0.23	1.19 ± 0.19	1.15 ± 0.24	.091*	1†	.0913†	1†

LDN, laparoscopic donor nephrectomy
* One-way analysis of variances among groups
† Post-hoc analysis with the Bonferroni correction method‡ χ^2 test
§ Fisher's exact test

proficiency is achieved with 75 cases on average [13], while others affirmed that the proficiency number is lower in centers with low volumes of LDNs (about 10 LDNs) but the presence of dedicated expert assistance is mandatory [15]. The United Network for Organ Sharing recommends that a surgeon should have performed or assisted with 15 LDNs to be considered fully trained. Serrano et al suggested that transplant surgery fellows require between 35 and 38 cases to become proficient with LDN, demonstrating a tipping point of the learning procedure at 24 to 28 cases in a fellow's transplant education program [18].

This considerable range in the number of cases deemed necessary to become proficient in LDN could deter small centers from starting LDN programs and in order to shorten the process of LC, some authors prefer a hand-assisted laparoscopic approach (HALDN) because it could represent a "bridge" from open surgery to fully laparoscopic donor nephrectomy, helping surgeons to gradually improve their laparoscopic skills necessary to perform a pure LDN [19].

In the present experience, we used as a surrogate method to objectively assess surgeons' performance the measurement of operative time because blood losses and intraoperative or postoperative complications were too low to be used as proficiency indices. Therefore, it can be reasonably assumed that no issues regarding donor safety should be raised, even in the first phase of a center's LC, encouraging the development of a mini-invasive strategy in a growing number of transplant centers. Nevertheless, it must be mentioned that the volume of procedures for a center is likely to be the most important factor in determining the incidence of perioperative complications. Patel et al found that centers performing ≤50 cases/year had more than twice the risk of perioperative complications compared with centers that performed >100 cases/year [20].

The rate of complications in our study is in line with current literature, showing only one case of conversion to laparotomy. Our transplant center has become a high-volume center during the past 17 years (Fig 5), currently performing about 50 LDNs/year.

The CUSUM analysis of the LC of the entire team (Fig 1) shows that operative time starts decreasing after 157 LDNs. The ascendant phase of LC includes all LDNs performed by the first surgeon (who performed 30 procedures solely in this phase), 55 performed by the second surgeon, and 72 by the third surgeon. In this phase, each surgeon took advantage of the experience of the previous surgeon, allowing the technique to gain standardization and safety, but this could not reduce LC for each surgeon. It must be clarified, however, that the tipping points for different surgeons may not overlap in terms of absolute value of the operative time: the analysis of 3 different surgeons is not aimed at comparing their proficiency, but

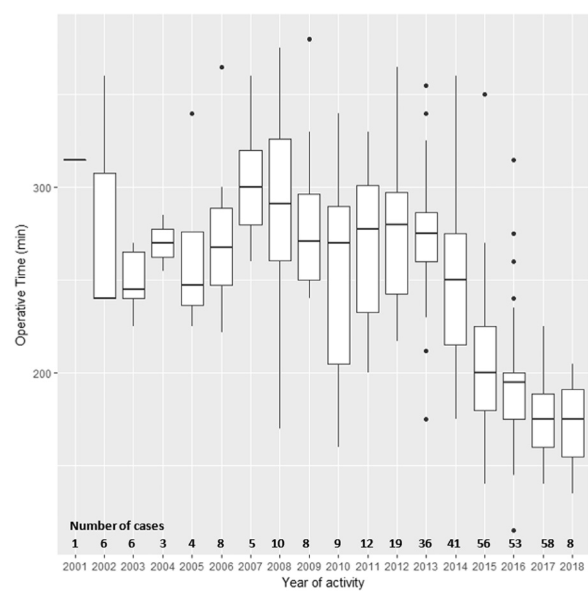

Fig 5. LDN operative time box plots by increasing activity years at the Kidney and Pancreas Transplantation Unit at Padua University Hospital. The series of box plots, which represent the median, 25th percentile, 75th percentile, the maximum and minimum values, and the outliers of the operative time from 2001 to February 2018, showed a clear improvement in terms of shorter operative time with increasing case experience and a reduction in variability in the last few years of the activity. (In 2004, 2014, and 2018 the median operative time was 270, 250, and 175 minutes, respectively.)

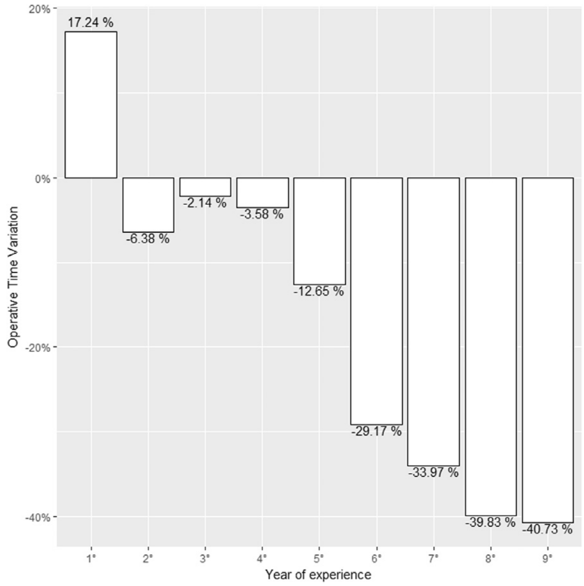

Fig 6. LDN percent variation in the mean operative time of the third surgeon compared with the first case (0 experience) and number of cases per year indicated in the boxes.

evaluating the progression of each of them throughout the accumulation of experience. Developing expertise and reducing LC is the goal for each surgeon, but alternating surgeons in the procedures is not recommended to achieve it until one surgeon completed his LC.

We investigated the percent variation in the mean operative time of the third surgeon over the years. This analysis was helpful to understand how much time is necessary to get expertise in LDN. Compared with his first case (ie, no experience), 3, 6, and 9 years of experience were associated with 2.14%, 29.17% and 40.73% reductions respectively in the operative time (Fig 6).

The current literature does not reach consensus about the number of LDNs necessary to achieve proficiency in this procedure. The number's heterogeneity could be interpreted as focusing attention on the background of the surgeon who performs LDN. This is a tipping point to consider during a LC's evaluation. Currently, different kinds of surgeons with different types of surgical training perform LDN in transplant centers: urologists, general surgeons, and transplant surgeons.

At our center, general surgeons with different surgical training performed the LDN over time: the first surgeon had advanced laparoscopic skills without transplantation experience, whereas the second and the third main operators were mostly transplant surgeons with limited laparoscopic experience. In the urology unit, where laparoscopic nephrectomies are performed routinely for different medical conditions, the number of cases necessary to reach proficiency could be much different compared with a general surgeon who deals with kidney disease less frequently. Friedersdorff et al recommended training in laparoscopic radical nephrectomy for cancer, under the supervision of an experienced urological laparoscopist, before performing an LDN [21]. On the other hand, unless directly involved in renal transplantation, urologists may not display familiarity with renal vessels' length and vascular reconstructions as compared with an experienced transplant surgeon.

Patients' characteristics can also influence the number of cases necessary to achieve expertise in LDN. In our LC there was no statistically significance when looking at population features across the 3 learning phases, whereas there was a slight difference when considering WIT (Table 6). WIT depends on surgical technique (usually WIT is lower in HALDN than in LDN) [21], back table's surgery, and on the type of stapler used for vascular stapling. In the first 75 cases at our center, 2 different staplers were used; only afterwards, a single stapler with 2 cartridges was used for each procedure. Therefore, WIT increased over time because some seconds were needed to replace the stapler's cartridge.

Prolonged WIT has been considered one of the major disadvantages of pure LDN compared with HALDN or open nephrectomy [22]. Some authors reported that longer WIT is not related to adverse effects on graft outcome [23]. Others found that it is independently predictive of poor early graft function in LDKT [24]. Certainly, this matter should be subject to future investigation.

CONCLUSIONS

LDN is a safe procedure with low rate of complications if a skilled surgeon performs it. Learning the technique is an articulated process that requires time. Our results suggest that a surgeon starting an LDN program needs up to 75 cases to reach proficiency, and his or her performance sharply improves 4 years after the first procedure (ie, the time necessary to complete the LC ascendant phase in the present experience, depending on the center's procedural volume).

The number of cases needed to achieve expertise in LDN is still being discussed because technical background and competence of surgeons who perform LDN could be very different. The introduction of a specific transplant fellowship with a learning program focused on LDN and LDKT is deemed necessary to standardize the number of cases required to reach proficiency in this complex procedure.

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